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MENLO PARK REMINISCENCES — JEHL

VOL. 2

MENLO PARK REMINISCENCES

VOLUME TWO

—

FRANCIS JEHL

MENLO PARK

REMINISCENCES

BY

FRANCIS JEHL

Staff laboratory assistant of
Thomas Alva Edison
at Menlo Park

VOLUME TWO

Written in
Edison's restored Menlo Park laboratory

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PREFACE TO SECOND VOLUME

In 1928 Mr. Henry Ford, in a letter to Francis Jehl, wrote:

> 'I hope that you will have many years to continue the work you are doing to establish for all future generations the name and fame of our great friend Mr. Edison.
>
> 'I feel that we are serving posterity when we make certain of transmitting to them the knowledge of his life and work.'

Before receiving that letter, Francis Jehl had completed a pamphlet describing some phases of Edison's early work and the great inventor himself commented on it in a letter to Mr. Jehl:

> 'Your pamphlet is very well written and interesting—it is a valuable document and I want to compliment you on your historical accuracy.'

With the restoration of the original Menlo Park laboratory in Greenfield Village, Dearborn, the memories of those Menlo Park days have been recalled and placed on record in these 'Reminiscences.'

The second volume now completes Mr. Jehl's intimate and true story of Edison at the greatest period of his career, those years at Menlo Park whose brilliant exploits gave to the world the Edison universally honored today.

The 'Reminiscences' also include a list of the men who assisted in that great work at Menlo Park. Many mistakes and much misinformation published in the past have been corrected. 'Reminiscences' such as these could not have been written by an outsider, for only one who was associated with Edison in his research laboratory from the beginning of his work on incandescent lighting could present the facts as they actually were.

That these 'Menlo Park Reminiscences' have not been written in vain has been evidenced through the many thousands of copies of Volume I that have been sold, and by the numerous letters of praise and commendation that The Edison Institute has received since its publication.

We are confident that Volume II will be found even more valuable and interesting.

A third book dealing with the introduction of the Edison system in Europe and America is in preparation.

—William Adams Simonds.

PART THREE

(CHAPTERS LIV TO LXIX)

Early Development of Incandescent Electric Lighting

As told by
FRANCIS JEHL

FROM 1879 to 1880

ACKNOWLEDGMENT

TO VOLUME TWO

I HAVE been exceptionally fortunate in serving for years, two great and world-known leaders—one, Thomas A. Edison of Menlo Park—the other, Henry Ford of Dearborn.

To the latter I am especially grateful for enabling me to carry on the work that the former had urged me to do sometime before he passed away.

Charles L. Clarke once wrote me, 'A proper biography of Edison will be written long after you and I are gone.' And, 'For this biography yet to come, you are setting a correct picture of him in connection with his doings in the Menlo Park laboratory, which has heretofore not been done with accurate fullness. Keep on.'

In Volume One I have given the first real inside perspective of how the work proceeded at the Menlo Park laboratory. Here, too, for the first time and for the future is given the record of Edison's staff assistants and others engaged there.

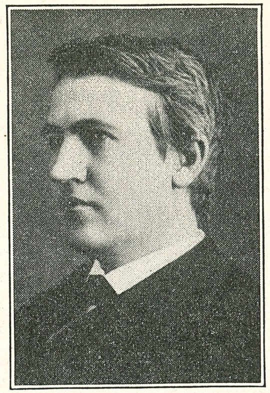
Few seem to realize to whom they are fundamentally indebted for the welfare they enjoyed after Edison and his Menlo Park disciples taught them the gospel of incandescent lighting. Fewer still have ever known or heard of Edison's first pioneer—the mentor who stood so loyally always at his side and to whose firm but gentle influence and forebearance, Edison and the world in turn owed so much. This first Edison pioneer's name was—Mrs. Thomas A. Edison, born Mary Stillwell. I have endeavored in this volume to pay tribute and describe her contribution to her husband's success.

I further desire to acknowledge my indebtedness to hundreds of my friends and others in different parts of the world for the reception that my 'Menlo Park Reminiscences,' Volume One, has received.

As an eyewitness, I have given a faithful account of the Menlo Park historical drama and all those that were concerned in it. The appearance of the third large reprinting of Volume One has assured me that my work was not in vain.

Again I wish to extend to Mr. William Adams Simonds, author and editor of *Ford News*, my thanks and appreciation for the pains he has taken in editing this second volume.

FRANCIS JEHL.



EDISON, about 1880.

LIV. The World in 1880

WHEN the year 1880 opened, Rutherford B. Hayes was President of the United States with only a short time left to serve. Senator Conkling, of New York, while himself tacitly a candidate for the office, was ready to urge General Grant for a third term if that measure should be deemed necessary to defeat the magnetic statesman from Maine, James G. Blaine.

The previous year had been one of great prosperity throughout the country. On account of crop failures abroad, wheat had risen to new high levels and other commodities were soaring as well. New industries were being born and among them none held greater promise for the future than the infant electrical industry Edison was carefully guarding at Menlo Park.

Edison's activities in electric lighting had brought America strongly to the fore in that field. Professor Trowbridge could no longer say truthfully that she was lagging behind the continent. By the end of '79 the world's attention was focused on Menlo Park, anxiously awaiting the new system of lighting. Critics, savants, skeptics, rivals—one and all watched every move of the Wizard.

The year 1880 promised to be just as busy for Edison as 1879 had been. The exhibition of the paper horseshoe lamp demonstrated the success of his experiments and at the same time showed him to be in possession of the fundamental principles of general electrical distribution.

Edison knew that the invention of the light had been accomplished. He also realized that, like all new inventions, his lamp must be continually improved. He again ransacked Nature's warehouse; he ran through old notebooks for names of substances tried once and marked: 'T. A.' (try again).

As time went on he searched everywhere for a carbon that would be denser and more homogeneous under the microscope than those hitherto found. It was a question of getting the best material for such a carbon filament.

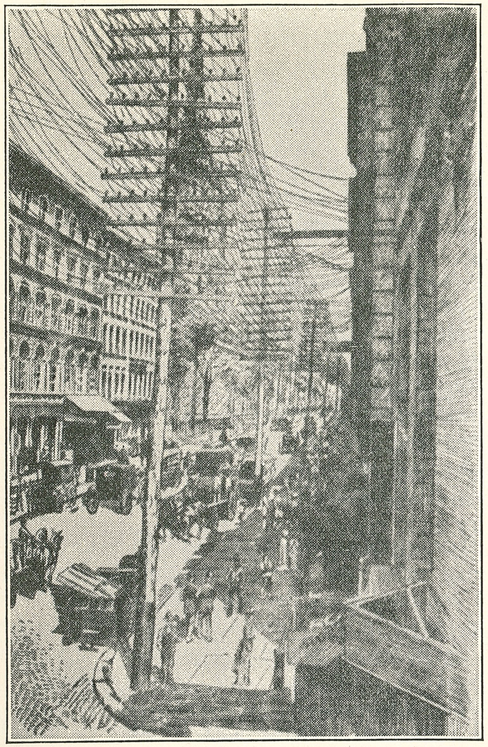
Edison's great invention of a practical incandescent lamp was not due solely to the use of carbonized thread or paper in the filament. Use of a specified material was an irrelevant factor. The moment of invention had occurred even before he made his first successful lamp. It occurred when Edison's reasoning powers decided that an incandescent electric lamp must have high resistance, small radiating surface and durability. Once that decision had been reached, he investigated various materials and achieved success with a 'filament *in vacuo*.'

During the 1879 experiments he had sought to overcome obstacles pronounced by others insurmountable. He had made a carbon filament of high resistance and small radiating surface that was able to withstand the terrific heat of the current. Having achieved that objective, he was now ready to improve and develop it.

At the same time he was giving attention to his first commercial order, the installation of a plant on the S. S. *Columbia*. The first night at the theater is always a great one, for then the critics judge the play. Of like significance was this first order calling for the application of the lighting system in practice.

While installing it Edison was planning America's first practical electric railway as will be explained later. He also laid plans for the first commercial incandescent lamp factory in the world, using for the purpose the old building near by where he had once manufactured electric pens.

If I were to show a gilded brass brick to an audience, it would appear to them like one of pure gold; but if I were to



Scene in downtown New York in 1880 showing overhead wires and congested areas.

take it to an assayer, it would soon be pronounced worthless.

Years hence, no doubt, I could find members of that audience who would swear that my brick which they had seen glittered like gold.

Those witnesses had not questioned the physical properties of the brick when I showed it to them; they had been awed by its outward luster. Had one of them known to measure the resistance of the brick, he would have found it different from that of gold, and he would have been able to challenge me, proving the truth of the saying: 'Everything that glitters is not gold.'

After me, suppose an Edison had come along and shown a brick of pure gold. There would still be many to pirate his principle and to summon supporters to say they had seen a gold brick shown by me years before.

The fallacy in this sort of reasoning is the same as that which judges the value of a lamp by the fact that it gives light. If any one in the audience of those pre-Edison lecturers had been alert enough to inquire: 'What is the resistance of your lamp? Has it small illuminating surface? Has it life?'

he might have swayed the judgment of the audience. Alas, those early lamps had short lives; they were born but to die obscurely.

The ignorance of the early experimenters led them to go forth audaciously to impeach Edison's genius, actually believing that their gilt was the same as Edison's gold, and that the great discovery had been theirs years in advance.

Thus a burden of conflict lay ahead of Edison as he entered upon 1880 preparing for a second and final demonstration at the laboratory.

It can be imagined how busy he was with the special visitors who came from all points of the globe to see him personally or to question him about his new system. Confident that he would soon have a better lamp than the paper one, he planned another demonstration on a larger scale with five hundred lamps and with underground conductors.

He had to work rapidly; he knew that hordes of infringers would spring up and claim the lamp by merely changing its outward appearance, while appropriating the principles he had discovered.

Another group, fencing with old facts, would assert that he had done nothing new and, pooh-poohing his efforts, would say they had accomplished the same thing forty years before. They would recall lectures given by them before the scientific society of their home towns. The weak point in their story would be that they had done nothing about it thereafter.

For them, indeed, it seemed nothing new, because they had only a narrow idea of what a lamp should be. They had no conception of questions relating to resistance or radiating surface. They had a vision of durability, but failed to realize it because their light-giving elements were sticks, cylinders or ribbons of carbon. Yes, they had made such a lamp and shown it in their homes, in the laboratory, or before scientific societies.

A person of alert mood might have asked embarrassing questions. Was their lamp a success or a failure? Why did they not put it to practical use? Why did they wait to emerge from their obscurity until Edison came along and announced his success? Why had their experiment not received outside attention?

Such claim-jumpers as these never managed to do more with their lamps than could be shown on the lecture platform.

Their light had no commercial value, because it followed a wrong principle.

The Edison Electric Light Company was the first to attempt domestic lighting by electric incandescence on a large scale. The practical era of incandescence in lighting combined with a complete and detailed system of electrical energy distribution had its genesis at Menlo Park during the years 1879 to 1880.

The Edison company, however, was not the first electric light company in America; many others existed at the time, all of which were organized to exploit electric arc lighting. The arc lamp was a mechanical contrivance in which two carbon rods were held a certain distance apart and regulated as the current consumed them. It offered a great inducement to men of mechanical turn of mind.

The same may be said of electric generation that supplied current for arc lamps. Many inventors entered that field also and the number of forms of arc generators to appear in the electrical market was surprising. Field magnets and armatures presented every geometrical contortion. Each inventor thought that, in some special form, the Aladdin lamp lay hidden in a generator.

Magnetically as well as electrically, many of these systems were most imperfect; crude mechanical lamps and electric light carbons fell far short of what was needed. Where electric arc lamps were used—as in streets or squares—the light fluctuated, hissed or often threw off white hot embers. Carbons had to be replaced daily as a rule, and the lamps cleaned. Their line voltage was so high that it menaced life and property. As a consequence of the latter characteristic there appeared a new word in the language—electrocution—and a new method of capital punishment in the world!

Emergency service was always available to correct deficiencies that arose. Lamps often 'stuck,' whereupon a service man from the station would come and give the lamp-post a thorough shaking to set the lighting mechanism running again and so permit the carbons to strike an arc.

In Newark, so a story goes, the service patrol of the arc light station had an intelligent white nag named Jericho. This horse became so accustomed to his job that he learned to detect a dead arc lamp and could be trusted to stop beside the wooden post so that the driver could shake it. Being of a helping nature, Jericho soon learned to relieve the driver of

that task also. Stopping beside the post, the horse would strike it a vigorous blow with a hind hoof. If the lamp did not start burning at once, the driver would call: 'Sock her again, Jericho!' And Jericho would keep at it until the lamp resumed its burning.

I well remember the dazzling light of the arc lamp and the sharp shadows cast by it. These lamps were rated at thousands of candle power; yet in general their illumination was far from agreeable. Edison's critics brought out the fact that with the same consumption of power a single arc lamp gave more than ten times the candle power of his incandescent bulbs, and thus, said they, his system was doomed to failure.

Such foolish criticism was eventually discounted. And even Preece soon admitted that a street one thousand feet long would be better lighted with forty gas lamps of fifteen candle power than with one electric light of six thousand candle power. Today arc lamps are not considered for general lighting, while the glow lamp reigns supreme everywhere.

The first arc light company in America was the outgrowth of the Telegraph Supply Company, of Cleveland. In 1877 this company acquired the rights to make the Brush arc light apparatus, and in 1880 the name was changed to the Brush Electric Company.

The Weston Electric Light Company, incorporated in 1877, had its works at Newark. It used the Weston arc lamp and generator.

The United States Electric Lighting Company was incorporated in 1878. This company absorbed the Weston company and exploited both the Weston and the Maxim arc light systems.

The Fuller Electrical Company was started in Brooklyn in 1878 to exploit J. B. Fuller's inventions. In 1879 Fuller proposed arc lighting by means of a transformer system. After his sudden death before the fruition of his plan, one of his partners, James J. Wood, reorganized the company. Thus the Wood arc lamp system became well known in the early days: for Wood was a young man of exceptional abilities who rose to eminence as an inventor and a leading member of the General Electric Company.(1)

I might add that in 1880 the American Electric Company was incorporated, with works at New Britain, Connecticut,

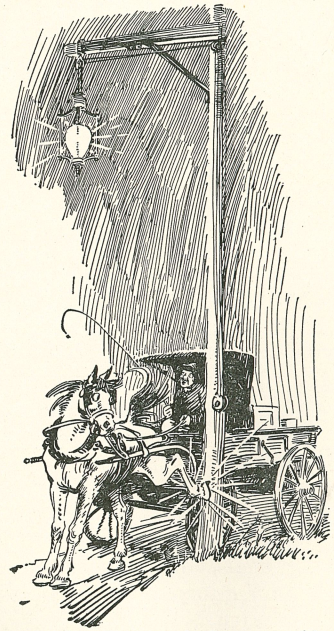
(1) The Edison Institute Museum in Dearborn, Michigan, possesses many relics of Wood's early electric light apparatus and efforts.

to exploit the arc light system of Professors Thomson and Houston, who with Brush later almost dominated the arc lighting of this country, and others.

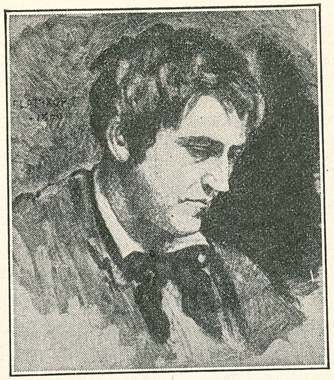
The Arnoux-Hochhausen Electric Company was also started in 1880.

The above names represent the leading undertakings in arc lighting. Many other companies were started in this country up to 1880, some to exploit arc lighting, and others, like blue-sky oil companies of later days, to sell stock to the gullible public. As I have already said, the Edison Electric Light Company invaded the electrical field because of the confidence of its promoters that Edison alone could bring forth a new system of energy distribution as well as a practical incandescent lamp.

Their faith was more than justified. For Edison solved the problem to the satisfaction not only of his stockholders, but of the entire world.



Stopping beside the post, the horse would strike it a vigorous blow with a hind hoof.

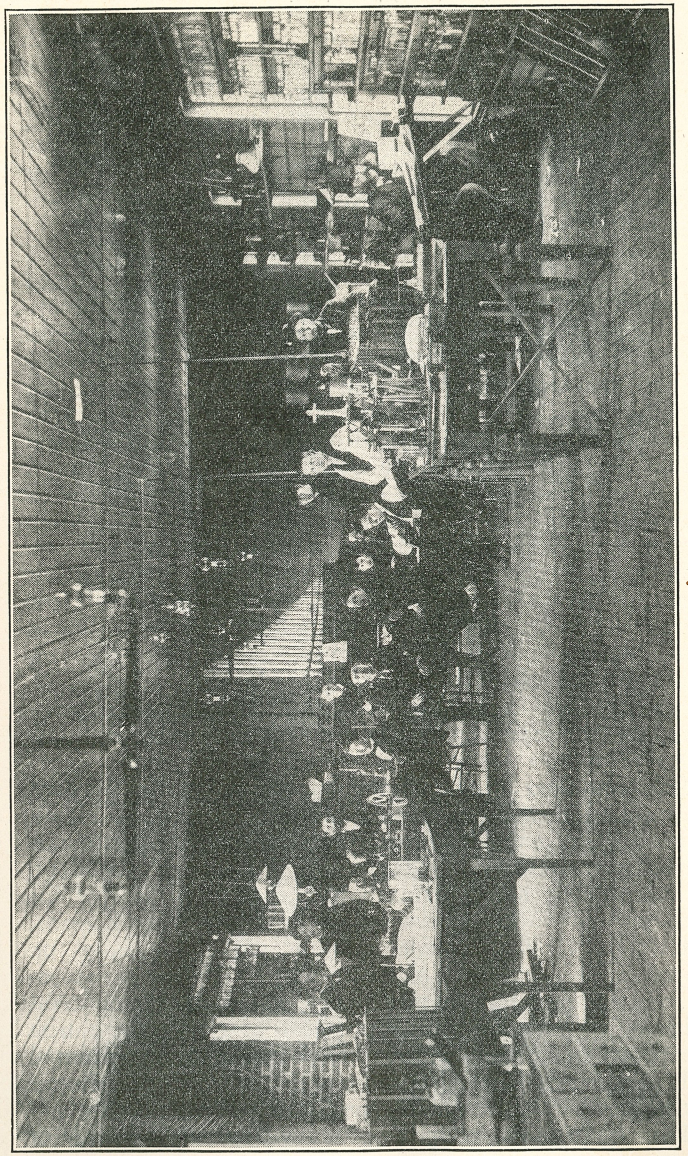


LV. Edison the Leader

BACK again in the old Edison laboratory, now at Dearborn, Michigan, I recall the thrilling days of '78-'81. I see the master at his work achieving for humanity realities that have since transformed the world. I reflect on the past half century: I fail to find words to express the supermentality of the man. The beginning and the end of it is, however, that when little was known of electricity outside a few basic principles, with Edison appeared the dawn of its practical possibilities, and that through Herculean labors the course of electricity has been diverted into the stream of a great progressive and industrial science which has promoted the living conveniences beyond all expectation.

Let me give you some of the impressions I have retained of the Edison of early days. In the first place, he possessed a magnetic personality that endeared him to all of us. To quote myself([1]): 'Those who were gathered round him in the old Menlo Park laboratory enjoyed his confidence and he theirs. Nor was this confidence ever abused. He was respected with a respect which only great men can obtain, and he never showed by any word or act that he was their employer in a sense that would hurt the feelings, as is often the case in the ordinary course of business life. He conversed, argued, and disputed with us as if he were a colleague on

(1) *Dyer & Martin*, Vol. 1, p. 297.



In the laboratory February 22, 1880. Left to right—Ludwig K. Boehm, Charles L. Clarke, Charles Batchelor, William Carman, Samuel D. Mott, George Dean, Thomas A. Edison, Charles T. Hughes, George Hill, George E. Carman, Francis Jehl, John W. Lawson, Charles Flammer, Charles P. Mott, and J. U. Mackenzie.

the same footing. It was his winning ways and manners that attached us so loyally to his side, and made us ever ready with a boundless devotion to execute any request or desire.'

He was the gentle master in everything—word, deed, and action; and we were but his disciples. Because he was the chief, harmonious working was assured his assistants; for he laid out the course of all experiments that were to be conducted, and gave hints and advice for procedure.

One of the most valuable elements in his character was a superb common sense that was rigidly logical. He attacked every problem in a quiet way but with logical persistency. Like many self-made men, he was not thwarted by obstacles but bore trials with patience and serenity. He knew that only through his own exertions and unremitting perseverance could the obstacles be overcome. He never became discouraged but made the most even of failure; in fact many of his best results were obtained through observations noted in what I may say were unsuccessful experiments. He possessed a marvelous memory and a mind crammed with facts that were always at his disposition.

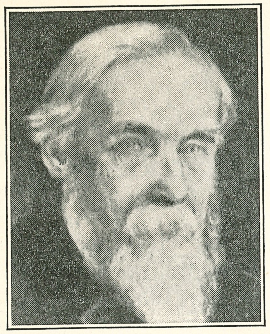
In describing the sterling traits of Edison, we must not forget that it was his own efforts alone that raised him from obscurity to fame. No countenancing or encouragement from outside placed him in a groove from which he obtained advancement; he had no protection nor did he ever seek it. Persistence and indomitable will power, quickness of perception, tact and ingenuity gained him the goal which but few have ever won.

His mind was an impetuous cascade of activity—which was not however that of a mere dreamer given up to delusions. Rather he was interested in the practical side of life. Whatever he undertook was generally well founded in possibility; his imagination never deceived him and the results of his work were always the reward of legitimate expectations.

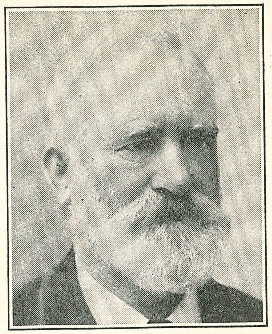
He was ever longing for more and more knowledge, on which, as it was attained, he built a natural method of reasoning from the laws dominating things material. A wonderful judicious ability in making physical diagnosis gave him ascendency in research work. Experiments were executed with a scrupulous integrity and a minute attention to detail that made him a master in the art.

Edison displayed surprising acumen in the solving of

American Contemporaries

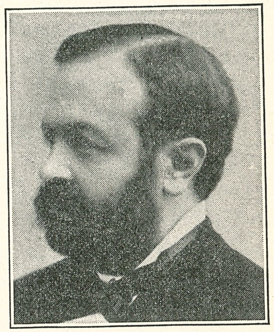


MOSES G. FARMER

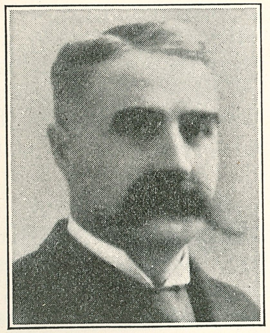


WILLIAM WALLACE

ELIHU THOMSON



EDWIN F. HOUSTON



CHARLES BRUSH

EDWARD WESTON

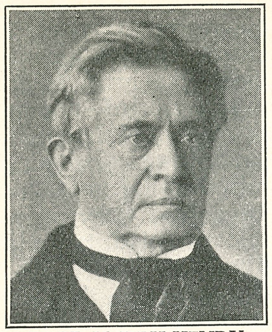
difficult problems. In this exercise of judgment he did not follow the beaten path of others, and yet never made the mistake of concocting the unreal. His simple ways of experimentation were often ridiculed by those who thought their own method exclusively scientific. His achievement, however, had proved beyond doubt that he possessed faculties which were pre-eminently developed through a vigorous scientific mind. He approached his work with the patience of the researcher, maintaining systematized order and generally surmounting difficulties by simply avoiding them.

What he learned, he learned well. His reason never accepted a theory that did not appeal to sense. And this good rule saved him from becoming a scientific bigot dependent only on book knowledge—which if never applied is as valueless as good tools to a man who cannot manipulate them. Edison recognized that inventions must be first conceived and then worked out either mathematically or in accordance with common sense. Being a man of easy expediency, he knew that if certain problems required mathematical ability he could employ a mathematician just as he could other assistants. It was due to this kind of initiative that he quickly outdid others in the development of certain ideas which jealous critics considered beyond his scope because of his lack of intimacy with mathematics.

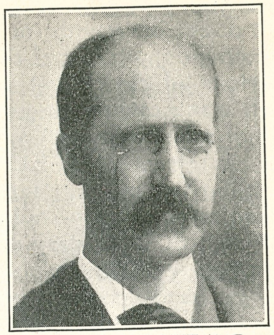
Edison's passion of intellect expressed itself just naturally in research work. In planning and providing for an experiment he was neither narrow-minded nor grudging but was open to every pertinent consideration and liberal to the extreme: nothing was too unusual or too costly to be used in the solving of essential problems. On the other hand he minimized waste; with care and diligence he would watch the details of an experiment, analyzing each phenomenon and seeking its practical application. While experimenting upon one idea he often found means of developing another. These methods were practiced until they became a natural element in every undertaking.

The foundations of pure science, Edison believed, were based upon incontestable truth. Truths, however, were often so clothed as to be difficult of recognition. In their quest he never crammed his mind with theoretical knowledge, but chose only facts that would serve as keys or detectors for useful ends. Common sense directed his operations chiefly

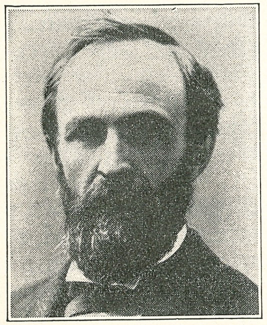
Scientific Contemporaries of Edison



PROF. JOSEPH HENRY
(Smithsonian Institution)



PROF. H. A. ROWLAND
(Johns Hopkins)



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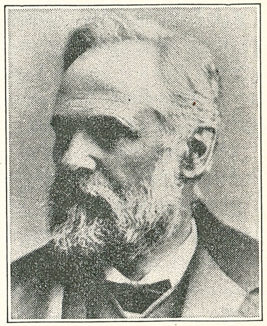
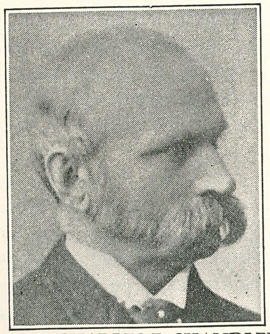
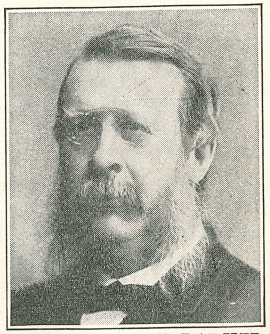
(Princeton University)



PROF. CHAS. A. YOUNG
(Princeton University)



PROF. CHARLES F. CHANDLER
(Columbia University)



PROF. GEORGE F. BARKER
(University of Pennsylvania)

toward extending the bounds of human knowledge in practical spheres.

No doubt his reputation as an inventor and as the creator of the phonograph forced the scientific world in general with its various adherents to take notice of all his undertakings, though many carpers among them still gloried in any opportunity of belittling him. When he announced the subdivision of the electric light and had the audacity to question existing laws relative to the lamp and the dynamo, he was attacked most bitterly—which proves that there is no critic so unscientific as a prejudiced scientist, and, according to the old saying: 'There's no fool like a wise one.'

When heads cooled, however, and even these learned gentlemen graciously condescended to examine his course of reasoning, together with its practical potentialities, many admitted the falsity of the inference that they—mortal men—had mathematically deducted from a false premise. They were wrong and the former train boy and newspaper seller was right.

Edison inspired his generation. He inspired them with constructive imagination to become productive; not to burden themselves with a superfluity of paper wisdom, but to gain experience from the realities. Whatever he undertook he did with accuracy, lucidity, and precision, virtues which should be numbered among every man's practices and applied in every walk of life. There is after all no romance about Edison; it is what he has accomplished through the exercise of human endowments that has the glamorous effect of romance.

His gospel was the elimination of waste, the cheapening of production, and the enriching of public utilities and conveniences. His various systems and improvements in duplex and quadruplex telegraphy, his carbon telephone transmitter, his motograph telephone receiver, the phonograph, the high resistance incandescent lamp, the low resistance armature, the Edison effect lamp, all exemplify the above assertion. Volumes could be written on the economy produced by his inventions and their world-wide influence on the advancement of civilization.

The name 'Edison' today represents a concept in which understanding, self-reliance and persistence have been blended to form one new element—useful accomplishment. The inward fires of genius and energy burned with a persistency which seemed to impel the man to acts of invention as if he were unconsciously the one chosen to fulfill an obligation of practical good to mankind.

He started with ideas alone—even lacking the means to back them. Gradually ascending the hill of fame, he reached a peak where he stood before the surprised world like the morning sun when it tops the ridge. His heroic figure remains as that of a superman who climbed nobly to the purest and most elevated glory. His accomplishments meanwhile had not carried him over corpses, his triumph had not made widows and orphans; no home had been darkened with grief by his victories. No questionable propaganda to allure the sheeplike multitude had been used to spread his system. No! his work was creative, and not destructive.

The intoxicating tendency of fame fostered no vain pride within him. Thomas Edison remained the same; he never changed face nor turned his cloak inside out. Quick success neither stultified his intellect nor stagnated his energy, as it has many who have gained a moderate degree because circumstances served them well.

Edison said, 'To stop is to rust,' and 'A harvest must be reaped occasionally, not once in a life.'

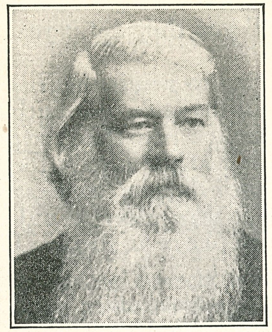
* * * *

Our narrative is still in the midst of the brilliant events that were exciting interest during the early part of 1880, with Edison, harnessed to his work as ever, now making rapid progress in commercially perfecting his system.

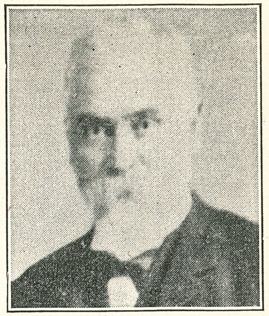
I well remember that forum of celebrated men whose pictures accompany this article; they were the high judiciary of the American scientific world whose verdicts were received by their partisans as positive law. There was Henry, the American Faraday. How surprised he was when Edison demonstrated to him his carbon telephone transmitter and phonograph! I have told of Barker and Edison at Rawlins, Wyoming; of Barker, Chandler and Edison at Ansonia, Connecticut; of Farmer with his platinum lamps at Salem, Massachusetts, and of the visits of Rowland, Brackett, Young and Barker at our laboratory.

At that time Brush, Thomson, Houston and Weston were busy with their arc light system, and none had faith in the little lamp that Edison had given to the world. That their disbelief was in error how well we now know! For the little lamp of high resistance still persists to this day.

Mrs. Sarah Jordan's Boarding House in 1880. Left to right: (at the gate) Alexander Mungle, Anton R. Westerdahl; John Lawson (in the window); William J. Hammer (sitting on railing); Miss Laura Jordan, Mrs. Sarah Jordan, William Holzer, Frank Holzer, Axel K. Westerdahl, colored servant; (on the street) William Mills, David K. Hickman, Thomas A. Edison, Jr., Thomas Logan, Ernest J. Berggren, Henry A. Campbell, John Raymon.



SIR JOSEPH W. SWAN



HIRAM S. MAXIM

LVI. Swan and His Lamp

ON NEW Year's Day in 1880 Edison received a cable from London, England, containing a copy of a letter sent to the editor of *Nature*, well-known English journal of that period. The cable read as follows:

> To the editor of *Nature:*
>
> I observe in *Nature*, volume XXI, page 187, a statement to the effect that Mr. Edison had adapted the use of carbon in his new electric lamp, and that the carbon he uses is charred paper or card in the shape of a horseshoe. Fifteen years ago I used charred paper and card in the construction of an electric lamp on the incandescent principle. I used it, too, in the shape of a horseshoe, precisely as you say Mr. Edison is now using it. I did not then succeed in obtaining the durability which I was in search of, but I have since made many experiments on the subject, and *within the last six months I have, I believe, completely conquered the difficulty which led to previous failures*, and I am now able to produce a perfectly durable electric lamp by means of incandescent carbon. (1)
>
> Joseph W. Swan,
> *Nature*, January 1, 1880.

'There you have it,' said Edison to Upton jokingly. 'No sooner does a fellow succeed in making a good thing than

(1) Italics are mine.

some other fellows pop up and tell you they did it years ago! Ever hear of this man Swan?'

'No,' replied Upton. 'He seems to admit that his paper lamp was no success, and so he is in the same boat with Starr, Lodyguine and those other experimenters who tried and failed.'

On Edison's request Upton searched the library for information regarding Swan. After two days of fruitless effort he found a short description in the *Scientific American* of July 12, 1879. The article was titled 'The Smoke of an Electric Lamp.'

At our meeting in December, 1878, Mr. J. W. Swan exhibited an electric lamp, on the incandescence principle, which had broken down in consequence of the electric force being too great for the *cylinder* of carbon through which it had to pass. One of the points of interest noted was the appearance of a sooty deposit on the inside of the glass. The flask which contained the *carbon pencil* and its platinum conductors, having been filled with nitrogen and exhausted with a Sprengel pump, was supposed to contain nothing that could act as a carrier to convey by chemical means any carbon from the incandescent pencil to the cooler surfaces in its neighborhood. The phenomenon appeared to be such as has been spoken of under the term 'volatilization of carbon.' Mr. Swan having placed the lamp at my disposal for examination, I have now the pleasure of bringing under your notice the results. Under the microscope the smoky deposit on the glass showed numerous bright globules, no doubt platinum, and more minute particles of dark matter nebulous under a quarter-inch objective. A fragment of the glass being exposed to an oxidizing heat, the deposit partially disappeared, still leaving the glass slightly darkened. The platinum support—which also had a coating of dark sublimate at a little distance above and below the carbon pencil, but not in immediate juxtaposition with it—was next examined by exposing to the blowpipe flame the unsmoked portion, so that the conducted heat might act upon the deposit without the fear of the blast carrying away the matter, which was very loosely attached. In this way the deposit was burnt off without the mechanical action of the blast, the heat to which it had been subjected being that of dull redness. A piece of the glass was then treated with *aqua regia* for several days. The deposit was diminished, but far from being entirely dissolved; the solution gave a blue reaction with yellow prussiate of potassa, and no coloration with tannin till aided by vapor of carbonate of ammonia, when the usual purple color of ferric tannate was developed. There is thus evidence of the deposit containing platinum, carbon, and iron. Probably the scattering of platinum globules might result from the disruptive discharge which took place at the moment of the lamp breaking down—B. S. Proctor, in the Newcastle Chemical Society's *Journal*.

'Did you look in the English *Engineering* and *Electrician*?'

'Yes,' said Upton, 'I have as yet found no evidence in them of anyone named Swan.'

'Well,' said Edison, 'if his experiments had been successful the world would surely have known it before now. Like the others, he tried pencils or cylinders of carbon, and then gave up. Now that I have succeeded, they are all reporting.

We shall have others telling us that they too did the very same thing.

'I believe their bid for recognition is proof that my lamp is known to the world today and has already received recognition, though some of my friends still attempt to belittle it.'

As time went on, we obtained more information about Swan, which I will include at this point. The lamp he claimed to have made fifteen years before—without success—used carbonized paper a quarter of an inch in width which could under no stretch of the imagination have been termed a filament. Edison worked with one-thousandth of an inch. It is evident that a carbon one-quarter of an inch wide could not be used commercially, even if (at that period) it could have been made to last for any length of time. Such a lamp had high radiating surface and low resistance.

At that time, doubtless, Swan had not determined what qualities a practical lamp should have: published evidence indicates that even after the Edison lamp had been known for months, Swan still did not grasp the situation. To say he had used paper in a horseshoe form fifteen years before did not entitle him to recognition ahead of Edison. The real issue was not who had used paper first but who had invented a lamp of high resistance, and small radiating surface.

Coming down to 1879, we find in the *Scientific American* article that the new light-giving element used by Swan was a cylinder (or pencil) of carbon. That fact alone precluded it as a practical lamp in a general distribution of domestic lighting for the reason that it was no more successful than the first.

I could mention many such lamps similarly unsuccessful. Here is a description of a low resistance lamp made by an American professor which can be found in the old American Telegraph Journal *The Operator*, issue of December 15, 1874:

A thin ribbon of carbon is suspended between platinum poles and covered by a globe containing dry carbonic acid gas. The ribbon receives the current from a battery, and while in the atmosphere of the gas becomes brilliantly incandescent. The carbon is not consumed and the light is said to be perfectly constant. The method was invented by Professor Osborn of Miami University, who at first thought it necessary to use very thin strips of carbon, but the light is now produced with much larger ribbons and with little combustion. The heat has never, as yet, broken the small glass globe containing the ribbon. This light being constant and not requiring the combustion of carbon, may prove much more useful to scientific lectures than the ordinary electric or oxyhydrogen lights, both of which are troublesome to handle.

Osborn's experiment was a success as far as it related to platinum poles and ribbon of carbon, but failed to be of any value commercially.

Another noteworthy case came up during the lamp litigation, when infringers were busy and the high resistance carbon filament and small radiating surface principle was at stake. It appeared in a series of articles on 'Incandescent Lamp Development to the Year 1880,' written in December, 1900, by an old friend of mine, Edwin W. Hammer, an able lawyer and patent solicitor well qualified to write such a history. In a review of the principal men who had attempted to make a successful lamp or to develop the principle of incandescence he named one, Adams, who made his first lamp during 1865. He wrote:

Dr. Isaac Adams, residing at Gloucester, Massachusetts, during 1865-6 made a number of lamps with carbon burners, about an inch to an inch and a quarter long, about three-sixteenths of an inch in width and from .005 to .01 of an inch thick; these carbons varied in resistance from .69 to 1.2 ohms, and were made by filing or scraping a block or strip of carbon as thin as he dared to, then dipping it in sugar and then reheating, making it tough and dense. The carbons were cut from gas-retort carbon, blocks of plumbago, carpenters' pencils or from a mixture of lampblack, powdered coke and molasses.

The vacuum employed was as perfect as Dr. Adams could make it. Great difficulty was experienced in maintaining a vacuum because of cracking of the glass around the large platinum leading-in wires, made necessary to carry the large current (from 11.5 amperes to 18.8 amperes) required by his carbons. This was not overcome until he produced a special character of glass from which to make his globes, having the same coefficient of expansion as the platinum.

'I had no idea at that time'—1867-9—' of having done anything of any special merit, as I thought the introduction of a piece of carbon into a globe to a person who was in the habit of making Geissler tubes was not much of a trick; but I was interested in the fact as to whether or not the big platinum that I put in the glass would hold, because I have always considered—did then, and do now—that I made an invention there which was a useful one. That was my interest in the lamp, and that was about all the interest I had in it.'(2)

The Adams experiment involved all the principles claimed by Swan after he had heard of Edison's success. Adams had success; Swan did not attain it (as I shall show later on).

France also came in with a claimant named DeChangy, who said he had made an all-glass lamp using a rod of carbon as the light-giving element. This lamp was said to have been made in 1844. If his statements were correct (and we assume the statements of Adams, Osborn and Swan were also correct), Swan was behind many other experimenters. They

(2) See *Electrical World and Engineer*, December 1, 1900.

anticipated him. In their experiments they succeeded in producing the physical phenomenon of incandescence, which others had been doing since the time of Starr. Their attempts failed because the experiments had none of the fundamental qualities necessary to a stable lamp for domestic purposes. Their labors passed into oblivion; but when Edison came out with a practical lamp, these were recollected and supported with the claim of having accomplished the same thing at an earlier period.

Edison's announcement in 1878 that he had found the solution of domestic lighting by electricity caused a furor everywhere. The reception accorded his great invention by England was only as warm as a cousin might expect. Many of her scientists were coldly conservative in their opinions; many were trenchant. A Parliamentary commission was called to investigate. Eminent scientists and engineers were questioned concerning the possibility of substituting electricity for gas in domestic utility. All agreed it would be impossible.

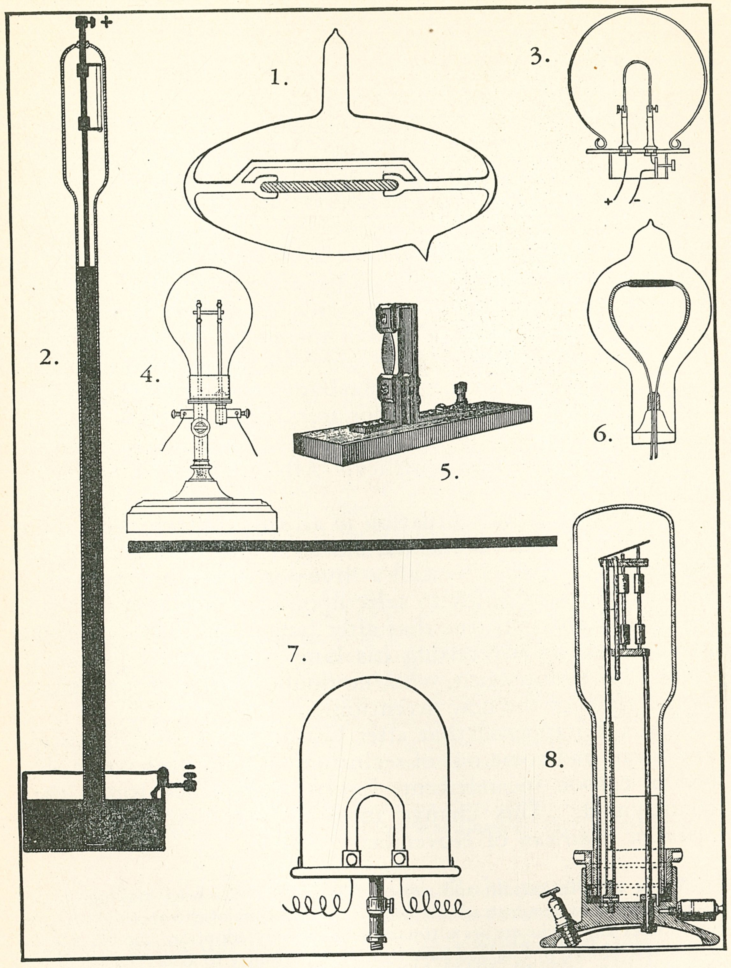
What was Swan's situation in all this controversy? Now Swan was not only a chemist but a busy lecturer and a good business man—what we call a 'live wire.' His biographers(3) say that 'he was quick to seize upon new facts and new conceptions'; and it is true that after January 1, 1880, he became most active in advertising his lamp. He gained adherents among his countrymen, who, no doubt, desired to participate in the glory of the new invention.

Thus it happened that after Edison had shown his wares and Swan had come out of seclusion claiming to have made a rod of carbon incandescent, Englishmen rallied round their countryman. This change in front was described in the *Scientific American* of November 27, 1880:

While all this certain and substantial progress has been making in this country, both to demonstrate the utility and economy of this method of lighting houses and to insure its ultimate if not speedy adoption, the electricians and practical men of England have lost no opportunity to assert the utter futility of any efforts in this direction. The ignorance and incapacity of Americans who, like Mr. Edison, have presumed to argue the feasibility of electric lighting by incandescence, have been ridiculed unsparingly, with much parade of mathematical formulae and alleged experimental demonstration; and not a little mock sympathy has been wasted on the deluded followers of the incandescent Will-o'-the-wisp which was leading so many Americans astray.

It is not a little amusing, therefore, to witness the sudden conversion of

(3) *Sir Joseph Wilson Swan, F. R. S.*, Ernest Benn, Ltd., London, 1929.



EARLY ELECTRIC LAMPS THAT FAILED

1. De Changy's, 1844; 2. Starr's, 1845; 3. E. Staite's, 1848; 4. Roberts, 1852; 5. Farmer's, 1859; 6. Adams', 1865-6; 7. Swan's, 1860; 8. Konn's, 1875. Note: the writer was never able to find Swan's lamp (No. 7 above) illustrated or documented among early records or before Edison's lamp.

these decriers of electric incandescence to a fervent belief in the applicability and economy of such a system of lighting, simply by a single exhibition by an Englishman of what appears from the description furnished to be a close imitation of Mr. Edison's lamp, that is to say, the lamp which Mr. Edison, with characteristic effrontery, has been patenting as his own. As usual, it turns out that Mr. Edison has merely copied, with phenomenal exactness, an invention which an Englishman made years and years ago, but strangely neglected to make public until some time after Mr. Edison's alleged invention had attracted world-wide attention.

Before leaving the Swan-Edison dispute, I will relate another incident. The reader will remember Edison's experiments with occluded gases as related in Chapter XXXIV. That work was also fully recorded in his United States Patent No. 227,229, signed on April 12, 1879. Further, he presented a paper on the subject before the summer session of the American Association for the Advancement of Science at Saratoga, which appeared in print in various technical journals in America and abroad. The English magazine *Engineering* printed it on October 10.

Imagine our surprise when we heard that Swan patented the process in 1880! His biographers say: 'This important discovery, made before the close of 1878, was in fact the key to the solution of the great problem of electric lighting by incandescence.'

Why did not Swan get his patent in 1878, if he considered the discovery so important? Why did he wait until Edison claimed it?

We have yet to see a printed record of Swan's claim. As Edison often said: 'Seeing is believing.' We were certain none was made anywhere in any publication.

As the world knows, we used this discovery of Edison's in all our lamp experiments during 1879. It was on official record everywhere. The claim of Swan one year afterward seemed preposterous.

The *Scientific American* of November 27, 1880, commented satirically:

At a meeting of the Literary and Philosophical Society, Newcastle-on-Tyne, October 20, Mr. J. W. Swan delivered a lecture on electric lighting, and exhibited a lamp in which light was produced by the incandescence of a slender ring of carbon in a vacuum. In the *Electrician* of October 30, there appears a three-page abstract of Mr. Swan's lecture, and other scientific English papers of corresponding date devote much space to the discussion of the lecture, the new lamp, and the newly demonstrated efficiency of electric lighting by incandescence. We fail to find, however, either in the abstract of the lecture or in the

engraved illustration of the lamp, any strikingly original discovery or radical novelty—barring, of course, whatever has been pirated in advance by Mr. Edison and other American inventors and made known in reports of their alleged experiments and inventions. Mr. Swan's plan of distributing the current to his lamps may deserve notice at another time. While pumping the air out of the globe of the lamp, and when the vacuum approaches completion, Mr. Swan heats the filament of carbon to incandescence to expel the gas occluded by the carbon in its cold state; otherwise, he holds, the outrush of occluded gas, the moment the current of electricity is turned on to the finished lamp, would destroy the vacuum, and presumably injure the lamp or lessen its endurance. This precaution Mr. Swan thinks highly important, and doubtless Mr. Edison will agree with him, seeing that he has taken it from the first. It was clearly from this practice of Mr. Swan's that Mr. Edison got his idea of treating platinum and other substances by electric heating *in vacuo*, as described before the Science Association a year ago last summer. This, however, is a matter of small consequence. The remarkable feature of the case is the sudden change of attitude on the part of many English authorities with respect to the possibility of the successful application of incandescence to the problem of interior lighting by electricity. American workers in this field can scarcely fail to be encouraged by so hopeful a sign.

In Swan's lecture on October 20, 1880, almost one year after Edison's invention of the first practical lamp and nine months after the publication of Edison's patent, he says: 'Instead of grouping the lamps as Mr. Edison proposes (he should have said "does"), each lamp being, as it were, a loop or bridge between two mains, *I propose to string them in series, 10, 50 or perhaps 100 lamps being all interposed in one and the same line.*'

This proposal demonstrated that even at so late a period Swan did not yet understand the kind of lamp needed for domestic lighting. He still had in mind a lamp of low resistance, on which all of Edison's predecessors (except Lane-Fox) had worked without success.

It was unfortunate that a business man of Swan's sagacity could not show a single patent or application covering some effort he had made toward the incandescent lamp, until Edison had astonished the world with the product of his genius.

Starr, Staite, Shepard, Roberts, Konn, Kosloff, Farmer, Lane-Fox, Sawyer, Maxim and Edison obtained such official documents from the Patent Office. Swan alone waited till the work was finished before revealing that 'within the last six months, I have, I believe, completely conquered the difficulty.' And during those last six months he still did not consider his invention important enough to need protection by a patent application!

Things changed suddenly when Edison appeared on the

scene. Swan's business acumen now asserted itself. Before long he had a company of his own, The Swan Electric Lamp Company, Ltd., and a factory outside Newcastle. Thus he began a competitive race with Edison. Of course, Swan did not try to market that old carbon-rod lamp. No, he used a regular Edison carbon filament lamp with some slight variations in form. Later, he reorganized the company as The Swan United Electric Lighting Company, Ltd. At this point the English Edison Company was organized. Meanwhile Swan's backers had already invested considerable money and were actively engaged in installing isolated plants. They thus established a precedent and were well entrenched with a staff of able assistants, among them such men as Stearn, Ginningham, Edmunds and Crompton.(4)

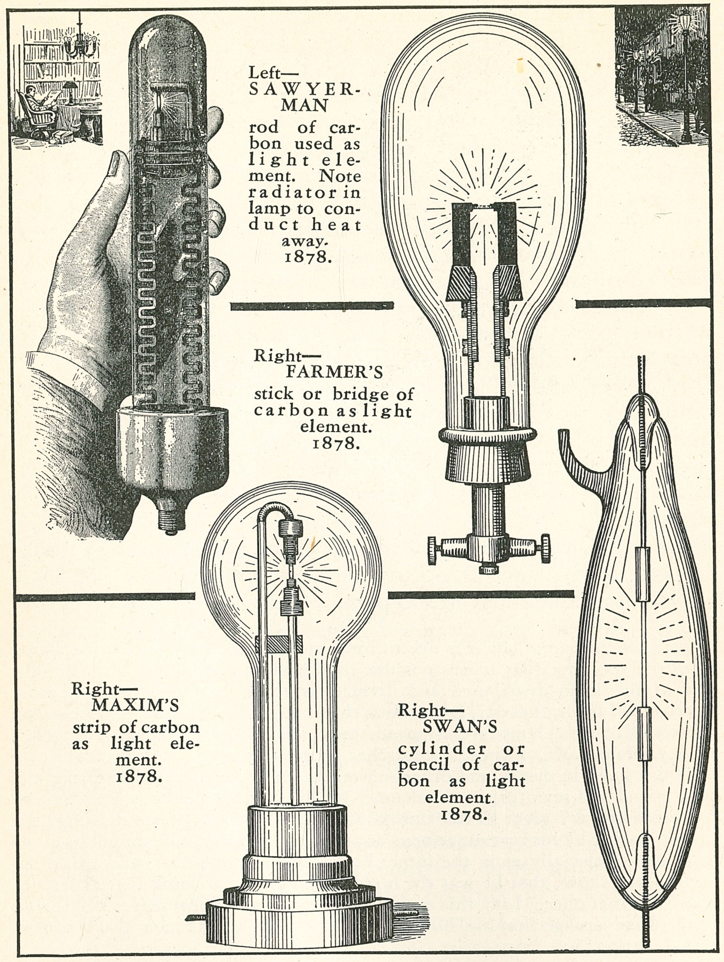
In 1880, after Edison had acquainted the world with his lamp and his system, Swan took out his first patent. He made carbon filaments (not rods) out of parchmentized thread. Edison had shown the world how to make a filament and it was not a question of what the filament was made of.

In 1881 a paper was read by Mr. Crompton before the Royal United Institution. A discussion followed in which Mr. St. George Lane-Fox took part. Said he:

> I think that great credit is due to him (meaning Edison) for having stated from the very first that it was possible to introduce a system of electric light that could be so distributed and divided as to be available for household purposes. I think that Mr. Edison was the first, and not Mr. Swan, to produce a practically useful lamp on the incandescent principle with a filament of carbon in a vacuum. Mr. Edison's researches, too, in respect to the presence of occluded gases in metals and other substances, are exceedingly interesting and very sound and scientific in the manner he has carried them out. I think he has rendered very great service not only to the future of electric lighting, but also to science by his investigations; and for this, proper credit should be given him, more especially as in the future he will be able to show, and I have no doubt, will show, that he was the first to succeed, and I think it is as well to recognize it at once. I say this entirely disinterestedly, because it is very much to my disadvantage that Mr. Edison should be the first, as I have also claims in this direction.

Lane-Fox, as I have already said, was the only man who understood the principle of high resistances for incandescent lamps. Yet 'he did not know how to make an efficient carbon lamp filament.'

(4) When Edison sent me to Europe in 1882, I had the pleasure of meeting R. E. Crompton, whose arc lamp was well known at that period in England.



EDISON'S PRINCIPAL RIVALS

Experimental lamps that existed before Edison invented the first practical carbon filament lamp for public supply. Those of Farmer, Sawyer and Maxim are documented by patents of 1878. Swan had no patent and the illustration given seemed to have appeared first after 1880. Any one of them was inapplicable to central station service.

In 1883, the English Edison Company decided to challenge the Swan Company. Cooler heads, however, brought about the consolidation of the two under the name The Edison and Swan United Electric Light Company, Limited. They followed the example of the merger between the telephone interests of the Bell and the Edison telephone companies. This combination of Edison and Swan possessed many legal advantages so far as competitors were concerned, and at the same time enabled the utilization of their money to better advantage than wasting it in lawsuits against each other. It also brought out a history of Swan's claims which put him properly among other predecessors of Edison who, working on the wrong principle, had failed to produce a practical commercial incandescent lamp.

In 1886, the Edison and Swan Company sued Woodhouse & Rawson as infringers. The suit was paradoxical in many ways: the inventions of Swan (a plaintiff) which he claimed had antedated Edison's were discussed frankly by the court. The case was won on the merits of Edison's patents. Justice Butt of the English High Court of Justice said:

> . . . The question therefore is, and the main question to my mind: Are Swan's carbon rod or pencil and Mr. Edison's carbon filament practically the same thing. Now, I think they are not . . . Mr. Swan's carbon rod or pencil is not only different from Edison's carbon filament mentioned in Claim 2, but it is totally and wholly different.
>
> . . . Mr. Edison's conductor possesses a smallness of cross section combined with other properties which Mr. Swan's does not. Mr. Edison's conductor possesses a degree of flexibility which to my mind is not even approached by Mr. Swan's . . . In the lamp that Swan produced, the conductor is a rod. . . . Now, I cannot help thinking that, at the time in question, not in January, 1880, but at an earlier period before Mr. Edison's specification, had Mr. Swan known of the various advantages of Edison's carbon filament as used, his lamp would never have contained a straight rod fixed at each end; and by straight, of course, I mean lying evenly between the two points of junction—a straight rod so fixed to the ends of platinum wires. Moreover, I think that there is no evidence to show that before Mr. Edison's specification he knew how to make a carbon conductor of anything like so small a cross section which would answer to the other requirements stated . . . The first time I can find Mr. Swan's conductor spoken of by him as a filament is in his Final Specification of the patent which forms one of the matters in this suit, and that is under the date of the 1st of July, 1880, Mr. Edison's Final Specification being some seven or eight weeks prior to that. He chooses to use it. What he read and what he did not read is unknown to me, but having at all events, if he had chosen to use it, the advantage of the knowledge conveyed to the public by Mr. Edison's Specification, it is true we do find Mr. Swan some weeks later calling his carbon conductor a filament. Now, a rose does not smell any sweeter for being called a rose, and the fact that Mr. Swan did subsequently call that rod a filament does not at all convince me that it is properly so called.

The case was carried into the Court of Appeal (Royal Courts of Justice). Lord Justice Fry in his judgment mentioned among other facts the following:

. . . On the 19th of December, 1878, Mr. Swan, one of the present plaintiffs, exhibited to the Newcastle-upon-Tyne Chemical Society a lamp constructed entirely of glass, containing *in vacuo platina* leading wires hermetically sealed into a glass, between which wires was suspended a rod, or pencil, of carbon, slender, but not so slender as to be described as a filament. This produced incandescent light for a while, and then the carbon rod bent or bulged downward in consequence, as it appears, of the electromotive force being too great for the cylinder of carbon, and the inner side of the glass was lined with a sooty deposit, which, on examination, proved to consist of platinum, carbon and iron. On the 3rd of February, 1879, Mr. Swan, in the course of a lecture to the Literary and Philosophical Society of Newcastle, exhibited a second lamp of the same construction which gave out a very considerable incandescent light for some twenty minutes. It has been on exhibit in this case, and appears, like the first lamp, to have become to some extent coated on the inner surface with a dark deposit. On the 2nd of March, 1879, Mr. Swan again described his lamp to a Gateshead audience, but it does not appear that he exhibited it, and from that time it has, so far as this case is concerned, disappeared from history, and this disappearance is, we think, cogent evidence that Swan's lamp as it was exhibited was not a practical success; that Swan could not do what Edison did, and that the difference between a carbon rod and a carbon filament was the difference between failure and success.

. . . Mr. Edison used the filament instead of the rod for a definite purpose, and by diminution of the sectional area made a physical law subserve the end he had in view. The smallness of size, therefore, was no casual matter, but was intended to bring about, and did bring about, a result which the rod could never produce, and so converted failure into success.

In another judgment where the Edison and Swan United Electric Light Company sued Holland (behind Holland was the Anglo-American Brush Company) we quote Lord Justice Cotton:

. . . We now have evidence, which was not before the Court in the former action, of what was being done by Mr. Swan and by Mr. Stearn after the experimental trial of this lamp. We have the evidence of Mr. Swan and of Mr. Stearn. We have had before us the lamp 'F.J.B.1 ' and we have the letters written by Stearn to Swan in 1879 and 1880, which were apparently admitted by Counsel to show what was being done by Swan and Stearn. We see that 'F.J.B. 1' was treated by them as a failure, and that their attempt to correct its defects led to lamps which differed more widely than did 'F.J.B. 1' from the lamp described in Edison's patent. This evidence assists the conclusion at which the Court arrived in the former action, that Swan's lamp of 1879 was not a success, and I think enables me to come to the conclusion that this lamp was an experiment which failed and was abandoned, and that the difference introduced by Edison was one which changed failure into success. But it was contended by the Respondents that, in fact, Swan had used for electric lighting incandescent lamps with carbonized thread burners before the 10th of November, 1879. Two witnesses, Proctor and Heaviside, stated that carbonized thread lamps were, in 1879, used by Swan. There is no ground for imputing dishonesty to these witnesses, but there was direct evidence by Swan that he did not make any thread-carbon lamp before 1880, or before a fire, the date of which is fixed as 17th of January, 1880, and I am satisfied that the witnesses were mistaken in fixing the date as 1879.

Lord Justice Lindley:

. . . That the Plaintiffs' carbon filament (by which is meant Edison's filament) was essentially different from the carbon pencil used by Swan in his lamp 'F.J.B. 1,' and Swan had not by that lamp anticipated the plaintiffs' patent (Edison's).

. . . The question of anticipation must be considered anew on the evidence before us. If Swan's lamp 'F.J.B. 1' had been a success instead of a failure, it would, in my opinion, have been an anticipation of the plaintiffs' patent. The evidence, however, shows that it was a failure, and that Swan had not gotten the key to success. His own efforts to improve this lamp show that he was not thinking of filamentous incandescent carbons, but of other matters.

. . . I agree with Lord Justice Fry in thinking that the point at which Mr. Edison's instrument departed from Mr. Swan's was crucial, and the departure, though slight, had all the merits of a new invention and produced a new apparatus . . . One mode of trying this question is to ask whether any one would make such a thing as Swan's lamp 'F.J.B. 1' if he took Edison's specification as his guide? I am convinced he would not; he would avoid and not reproduce Swan's carbon pencil, and would adopt Edison's type of carbon in the carbon filament.

. . . Whether the view here taken of the patent is correct or not turns, in my opinion, on what Mr. Edison did when he introduced 'carbon filaments.' That was, I think, a new departure of the highest importance in electric lighting, and if this be so, the claim is not too wide.

In Lord Justice Bowen's opinion we find statements regarding Edison's carbon filaments as follows:

. . . The merits of the filament, as distinguished from a rod, are manifest. The filament, or thread, has an extremely small sectional area; it is flexible before carbonization, and resilient afterwards.

. . . It appears to me, moreover, to be proved, not only that every successful lamp since 1879 which is available for multiple arc lighting has employed a filament, but also that there is no proof yet that any filament cannot be adapted to the patented combination.

If this is so, why is the claim too wide? It is not the fault but the virtue of the invention that it covers so large a field.

. . . But in any case I think 'F.J.B. 1' never was more than an experiment which was unintelligible on account of its failure and barren of all fruit, and which was regarded even by its inventor as practically valueless in the race. The correspondence between Messrs. Swan and Stearn shows, I think, to demonstration, that till the middle of the year 1880 Mr. Swan did not consider himself to be upon the right track. The dates put forward by the witnesses, Proctor and Heaviside, seem to be unreliable and inaccurate, and I think there is reason for believing that it was Mr. Edison's patent which led back the world of electricians to the true path. Certainly from the date of its exhibition the lamp 'F.J.B. 1' disappeared from history, until it was exhumed for the purposes of the trial in the Woodhouse case.

. . . I think this patent (Edison's) constituted a new departure in electricity.

I have given Swan's status before January, 1880. In a scientific as well as in a judicial sense the evidence leaves no doubt that his claims were never supported by the facts.

The same sort of happenings were taking place in America. Sawyer and Maxim, after decrying Edison's great achievement, calmly reconsidered their adverse opinions and started companies of their own to manufacture lamps on Edison principles. They, too, were later restrained in lawsuits. Defendants (unlike Swan, a plaintiff), they had patents for carbon rod or pencil lamps, whereas he not only had none but, further, had considered his work only as an unsuccessful experiment.

Before Captain Crompton's association with Swan, he too gave his opinion of the Edison lamp and system in a letter written to M. D. Conway, London correspondent of the *Cincinnati Commercial*.

In his article in that paper dated January 17, 1880, Conway gives the following extracts from Crompton's letter:

Nothing urged in the paper can alter my opinion that, up to the present date, Edison has invented literally nothing that bears upon the future of electric lighting. According to this account he has gone over a great deal of old ground. If he had been as great a reader as he appears to be experimenter, he could have saved himself a great deal of time and expense. All he now claims is easy to detect, for he has cleared the ground by saying that he now sees that all his elaborate arrangements for regulating the current, so as to prevent the destruction of the material rendered incandescent and thus luminiferous, are all useless and unnecessary—a fact of which we in Europe were already aware of. He, therefore, seems to have narrowed his claims to a morsel of carbon rendered incandescent in an exhausted globe, and also claims a new form of dynamo-electric machine.

Crompton then goes on to tell what other inventors had done before Edison. And it is a striking fact that he does not mention Swan.

Say that he really invents something that will make his incandescent lamp superior—he will then meet the real great difficulty. That is, want of economy in the use of the incandescent system.

Edison does not attempt to show that his lamps, even if perfected, will get over this main difficulty. He certainly does give some wild figures. He talks about each generating machine supplying some fifty lamps, and each lamp taking a minute fraction of a horsepower. But I am afraid he has never given us reason to respect his command over figures sufficiently to take these wild calculations for substantial facts, when they happen to be utterly opposed

to the observed facts and calculations of our own and the best American scientific inquiries into this subject.

They only seem to be the expression in figures of what he wishes to be the result aimed at; and these wishes we believe to be as far from realization as ever.

The correspondent closes his article with the following pertinent remark:

Having submitted this opinion, I need hardly add that if Edison shall ultimately put it all down by actual success, his fame will shine all the brighter, and such prognostications as these, and those of the *Engineer*, the *Saturday Review*, &c., will take their place with Dr. Gardner's famous proof that the Atlantic could not be crossed by steam, which reached New York by the first steamship!

That eminent English scientist, John Ambrose Fleming, M. A. D. Sc., F. R. S., in his book *Fifty Years of Electricity* thus described Edison:

'Distinguished as an inventor and discoverer during the last fifty years.

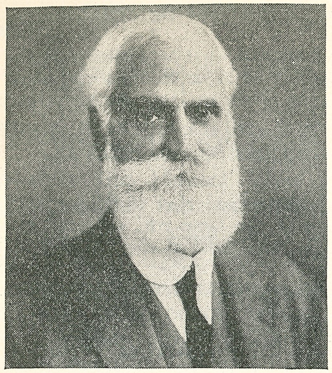
'Invented duplex and quadruplex telegraphy, the carbon telephone, the loud-speaking receiving telephone, the phonograph, *the incandescent lamp*; originated public electric supply, and numerous other inventions.'

That tribute and many others, as well as the world's homage paid to Edison on the fiftieth anniversary of his invention, confirm the opinions of those English judges of years ago, that he was in truth the inventor of the first successful and practical commercial incandescent lamp.

Thus we see that the lawsuits were won in England on the basis of Edison's fundamental patent, and the Swan claims were so thoroughly ventilated that little of them remained. The first time a successful incandescent lamp was shown in England was the early part of 1880. Fleming gives the following footnote:

The first two of these lamps exhibited in London were brought over from the United States at the beginning of 1880 by Mr. E. H. Johnson. He requested the author to make arrangements for exhibiting them in action. The author accordingly obtained some seventy bichromate voltaic cells to supply the 100-volt electromotive force necessary, and showed the lamps working in a basement room at 11 Queen Victoria Street, London, E. C., where at the same time the offices of the Edison Telephone Company, of London, were situated. They were shown to many people, and this was the first occasion on which Edison's incandescent electric lamps of this type were exhibited in action in London.

I may add that Johnson had come home from England to spend his Christmas in America. He often visited Menlo



ST. GEORGE LANE-FOX

Park, where Edison talked to him about the lamps used in the demonstration of 1879. Soon we all knew at the laboratory that Johnson was going back after New Year's, and that he was to take across several paper horseshoe lamps. These were the lamps that Mr. Fleming saw.

We see from Fleming's note that the lamps 'were shown to many people.' As Justice Butt would perhaps say: 'Who saw and who did not see them then is unknown to me, but probably those who were interested managed to see them or obtain good descriptions from others.' No one else in England, or elsewhere, had ever made such a lamp, and those who knew Johnson, knew that he spared no means to show Edison's greatest achievement to all the celebrated personalities of England.

St. George Lane-Fox was a British scientist, philosopher, inventor and experimenter. Contemporaneously with Edison he attempted to solve the problem of domestic lighting and, like Edison, knew what the characteristics of such a lamp should be. However, he did not succeed in making the lamp and was too honest and upright to start or enter into any nefarious scheme or plot in an attempt to rob Edison of his birthright.

Edison once said that he thought Lane-Fox would beat him, but it did not happen, for the trail that Edison followed was different from the trail that Lane-Fox pursued. Although Lane-Fox had patents and claims, yet this nobleman considered honor and justice above all. Disinterestedly, he publicly asserted that Edison was the first to make a practical lamp and that his discovery of the presence of occluded gases rendered very great service to science and to the future of electric lighting, and that it is well to recognize it at once.

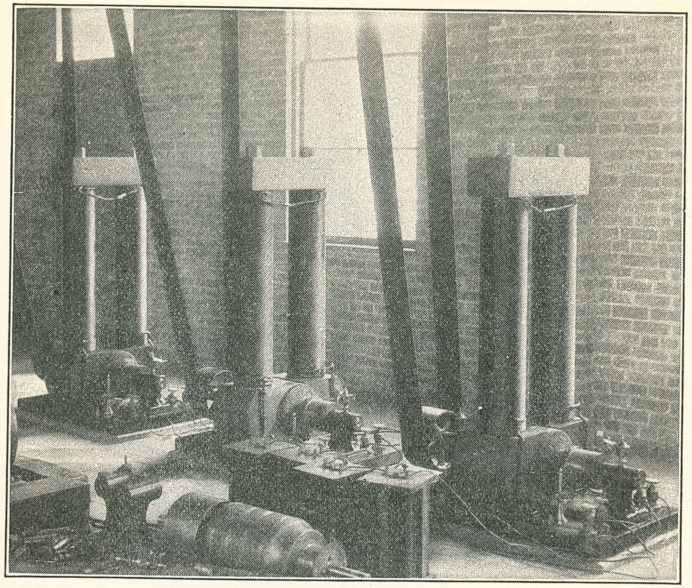
Mr. Ford starting Brown Steam Engine in restored machine shop, Dearborn.

LVII. The First Central Station and Lighting Plant

THE contrast between the world's first experimental central station for domestic distribution of electricity and a modern superstation may appear great; yet we know that in the nucleus of the modest central station installed by Edison at Menlo Park toward the end of 1879 were embodied all the elementary features.

The fundamental principles expounded by Edison at that time have formed the basis for the aggressive technical creations that have followed.

We know that in 1878 Edison began to lay his plans for a system of electric lighting and power distribution that would be analogous to the gas system; and he eventually conceived a method that promised success in competition. The key to the door of success was a cheap, practical incandes-



The first central station as restored at Dearborn in the Menlo Park machine shop.

cent lamp having the candle power of the ordinary gas flame. In addition, he must have an efficient dynamo and a flexible and constant potential system of underground conductors in which the cost of copper was not prohibitive. There were other necessary adjuncts, such as meters, sockets, fuses, switches, cleats and even insulating tape. For all these, not the shadow of a precedent existed from which he could start.

A writer once said: 'Edison is pre-eminently a modest man and was never known to ask for more than he thought he could get'; to which the writer wishes to add that whatever Edison thought he could get, he kept after until he got it. The herculean task he undertook to perform in 1878, which had so long baffled the world, was essentially solved in 1879, and when at last the impatient public had its opportunity to witness the first practical test, a feeling of widespread awe swept over everyone. With the exception of a few die-hards,

all realized that the dream of Sir Humphry Davy and other scientists was about to be realized.

The little central station was installed in the rear of the machine shop near the glass partition separating the shop from the engine room. It consisted of three Edison generators, of the 'A' type, each capable of supplying current for about sixty 16-candle power lamps with filaments of carbonized paper. The dynamos were strung in a line, tandem fashion, and belted to a shaft from the ceiling that got its power from a belt connected with the central shafting of the machine shop.

Between these two shafts (and in connection with the power-supplying belt) was a mechanical dynamometer by means of which the power absorbed by the dynamos was measured. If you will observe the accompanying illustration, you will see how the generators were mounted upon a wooden base. They had no switchboard on their yoke. Wires from armatures as well as field magnet coils led to four binding posts screwed in front of each wooden base.

There was no movable rocker for holding commutator brushes. Brush holders that could be moved up or down on a vertical metal standard were used. The commutator had seventy-five bars insulated by mica; the armature shaft rested upon bearings with *only* armature and commutator between them; the pulley was outside. These characteristics together with rounded pole pieces and shorter magnet cores define the earliest models of Edison's 1879 generators. The 1880 generators, such as were installed on the S. S. *Columbia*, had pulley, armature and commutator between the bearings; a disposition which was later practiced in the construction of generators at the Edison Machine Works in New York.

The first two generators shown in one of the accompanying illustrations delivered current. The third acted as exciter, its armature being in series with its own and the other two field magnet coils, together with a resistance box regulated by a crank handle. A loop from the exciter circuit crossed to the testing table in the research laboratory, where the resistance box was connected in series with it. At that period no convenient resistance box with a crank and steps had been designed for regulation purposes. Edison was the first to construct a resistance-regulating device with a crank handle, such as is in use everywhere today. This little contrivance reveals how Mother Necessity helped in devising

the many fundamentals that make up a central station.

Edison was also the first to introduce a constant potential system. In commercial service, something practical had to be designed to regulate the field magnet circuit. Plugging separate units in or out required the use of too much floor space. The Edison resistance unit of 1879, which was about one ohm, was made of copper wire. Bergmann & Company later manufactured these units for sale.

The little central station bus equipment was primitive; yet it answered its purpose. It consisted simply of four heavy copper wires mounted on telegraph insulators on the wall of the machine shop, whence they ran to a wooden bar nailed across the window. The wires from the two current-supplying generators were led loosely from their respective binding posts to the two top bus wires on the wall and connected up in multiple arc; those of the exciter machine led to the two lower ones.

An operation of special interest was the way in which Edison regulated machinery in the distant shop by turning a single wheel in the laboratory, one of the first instances of

The machine shop and its crew—1880. John Kruesi is at the door with William S. Andrews on his right. David Cunningham seated on stoop. John Ott is in front in shirt sleeves. The three men nearest tree are (left to right) William Mills, Ludwig Boehm, George Dean (son of Charles Dean). In group also are Milo Andrus and William Wright.

remote control of electric energy. Today the three generators in the restored Edison machine shop in Dearborn operate just as they did in 1879, one as an exciter and the others as current generators, the wires from the exciter being led to the laboratory testing table where the regulating is done.

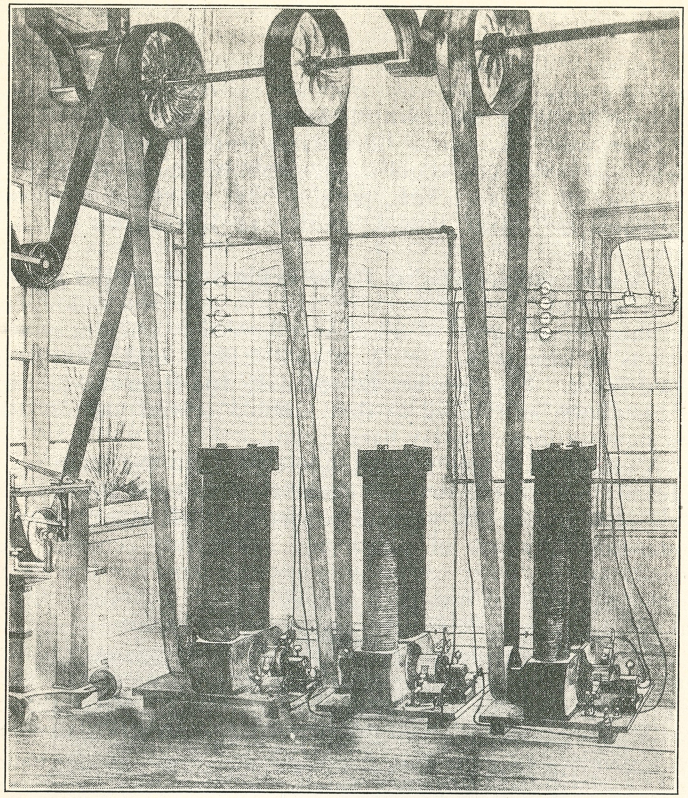
Fuses were used rather liberally in installations at Menlo Park; and it was one of our stunts to show visitors the short-circuiting of a branch line, proving that if such an accident happened no harm would result, as the circuit would be cut out.

We must not forget that at the beginning everything had to be learned; for we were invading a new and unknown continent the conquest of which was derided by eminent scientists as an impossibility. 'Seek and ye shall find,' says the Good Book. That is what Edison did; and from the results of his search as typified in that humble central station all the superstations of today have sprung.

A secret of success greater, however, than the lamp was Edison's idea of the ratio of external to internal resistance. This idea opened the path of progress for all practical and commercial systems of direct and alternating current. A transformer or rotary converter is nothing more nor less than a current receiver just as a simple motor or incandescent lamp is. He created the constant potential system.

How difficult it was for Edison to make his opponents understand this idea and how long before they did! The little central station at Menlo Park in 1879 supplied about one hundred lamps of the sixteen-candle type having filaments of carbonized paper; these were distributed among the residences, the Jordan boarding house, the laboratory buildings and the street lamp-posts; the same current also ran a small shunt motor connected with a sewing machine on the upper floor of the library. All street conductors were overhead, as were house connections and lamp-post wiring.

Of historical interest were the first lamp-posts mounted with incandescent lamps. They were of an improved design substituted about 1878 for the ugly coffin-shaped gas lanterns revealed in pictures of old New York. The new type of lantern consisted of a globe and a cover provided with an ornamental metal ventilation piece resembling an Austrian cuirassier's helmet; an incandescent lamp was placed in the globe. Posts at Menlo Park were painted white. The array presented a pleasing appearance.



Drawing of first central station as it appeared in 1879-1880.
(*From Scientific American.*)

The multitudes of persons who visited Menlo Park to see the incandescent electric lamps and the sewing machine working without pedals also saw for the first time a high-tension circuit from a new current-distributing system. Those who were unable to come learned of the wonders through newspaper, telegraph and cable.

Visitors were not all idle curiosity seekers; there were also men of note and agents for interested parties. And one man came for mischief!

That fellow had a heavy wire bridged across his shoulders

and concealed under his coat. By means of the ends, which passed out of his sleeves, he managed to produce a short circuit that blew out a local fuse, extinguishing a few lamps.

He was 'spotted' immediately; for we kept a sharp lookout during exhibitions. Before he knew it he had been rushed out. Other persons were trapped trying to steal lamps and whenever caught were not handled with gloves.

One day when thousands were there, the old frame laboratory creaked under the burden as if it would collapse. We averted disaster by regulating the number of persons allowed to enter at a time.

It is hard to appreciate the extreme difficulties Edison had to overcome before he presented his priceless gift to the world. Sir Oliver Lodge a few years ago said:

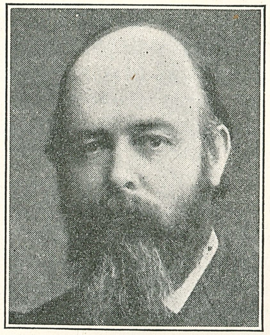
'Early pioneering work is too often overlooked and forgotten in the rush of a brilliant new generation, and amid the interest of fresh and surprising developments. I often think that the early stages of any discovery have an interest and fascination of their own, and that teachers would do well to immerse themselves in the atmosphere of those earlier times, in order to realize more clearly the difficulties which had to be overcome, and by what steps the new knowledge had to be dovetailed in with the old. Moreover, for beginners, the nascent stages of a discovery are sometimes more easily assimilated than the finished product. Beginners need not indeed be led through all the controversies which naturally accompany the introduction of anything new; but some familiarity with those controversies and discussions on the part of the teacher is desirable if he is to apprehend the students' probable difficulties. For though he does not himself feel them now, the human race did feel them at its introduction; and the individual is liable to recapitulate, or repeat quickly, the experience of the race.'

Sir Oliver Lodge was both humanly and scientifically correct. Let the teacher explain to his students how Edison attained his fundamental objectives. Let him show the common sense of Edison's methods and the practical results produced, extraordinary advances in science though disputed on every hand by men who thought they knew more than he.

The Edison incandescent lamp, the Edison dynamo, the Edison system of energy distribution for light, power and heat, form the exalted basic constituents of an art that has stood the test of more than half a century in all quarters of

the globe—of an order that from the start has been universal in its service to mankind.

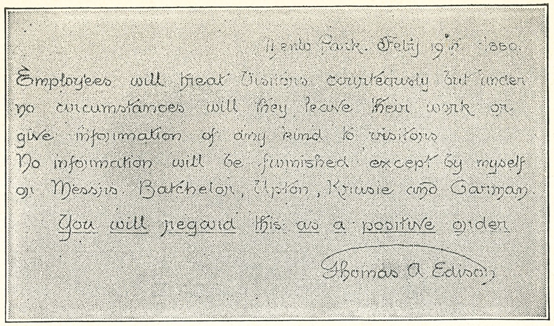
In Menlo Park at Dearborn may be seen the actual apparatus used in the great master's first demonstration of an electric light plant in 1879-80. Here you may see that first central station, that system of distribution and even those carbonized paper horseshoe lamps just as they were in the exciting days of '79-'80. Then again the most thrilling sight of all is the starting of this machinery in actual operation, when once more may be seen little paper incandescent lamps diffusing a mellow glow. A feeling of rapture carries you into the historic past where, under the enchanted spell of surroundings in the midst of which you have been magically placed, you come into mystic touch with Edison himself!



SIR OLIVER LODGE

Sir Oliver Joseph Lodge, scientist, physicist and mathematician, was born in 1851 at Penkhull, Staffordshire, England. He was professor at different universities and as a lecturer-author, was well-known. His research in electricity, especially relating to electro-magnetic waves, and his pioneer work in wireless has placed his name high in that art. In 1897 he took out a patent in syntonic wireless and emphasized the importance of 'tuning.' His researches also led to the 'Coherer,' which name he coined in the early wireless days, and, with the work done by Edouard Branly in France, a great advance or step was attained.

Sir Oliver Lodge, like Lord Kelvin, gave Edison credit for his discovery of 'Etheric Force' (see Volume 1, Chapter XIII) and the same has been identified in all respects with those rediscovered by Heinrich Hertz twelve years later. Hertz demonstrated their theoretical significance while Edison predicted their practical utility for wireless communication.



Menlo Park. Feby 19th 1880.

Employees will treat visitors courteously but under no circumstances will they leave their work or give information of any kind to visitors.

No information will be furnished except by myself or Messrs. Batchelor, Upton, Kruesi and Carman.

You will regard this as a positive order.

Thomas A. Edison

A copy of an order issued by Edison to halt indiscriminate handling of visitors. (Now in restored laboratory at Dearborn.)

LVIII. The Work Gets Under Way

THE *Scientific American* said in its issue of January 10:

> Mr. Edison has got the lamp he has so long been searching for, and curiously it is not at all what he thought it would be a few weeks ago. In other words, the light is generated in a strip of carbonized paper and not in a spiral of platinum or other refractory metal. The light produced is perfect; the lamp is inexpensive and apparently durable; the economy of the general system in which it is used is tolerably clear; and all its details seem to have been worked out with Mr. Edison's usual cleverness and practical skill. The only question that remains undetermined at this writing is whether the lamp will stand the test of time. It seems almost incredible that a slender thread of carbon can withstand the intense heat of the lamp, even in a perfect vacuum, without volatilization or fracture; but the lamps are stated to have stood action of the current, both in ordinary and in extraordinary strength, long enough already to upset all reasonable opinion as to the behavior of carbon under such conditions, and there is now nothing to be done but to wait for time to determine what the ultimate issue will be. The fact that all its predecessors in the field of incandescence have sooner or later come to grief is the chief, if not the only one, compelling a suspension of judgment in the present case. We sincerely hope that no hidden flaw may discountenance the inventor's confident assurance of victory. The light is exactly what the world wants to see; and if it will only wear long enough to pay for itself, both the inventor and the public at large are to be heartily congratulated.
>
> At this point it is proper to note the extreme simplicity of the new lamp and the lack of any startling novelty in its materials or construction. If the lamp justifies present expectation, it will have but one radical peculiarity, and that is success. And success, in a field beset with so many difficulties which men of science and practical experience have pronounced insurmountable, is the highest as well as the final proof of a great invention.

Less successful workers in the same field have been prompt to say: 'Mr. Edison is mistaken; the thing cannot be done as he claims to do it.' To which Mr. Edison replies: 'The problem appears to be solved; time only can tell whether the solution is final.'

The next objection is: 'The lamp presents no new discovery; its elements are old, and everything in the system has been suggested or tried before.'

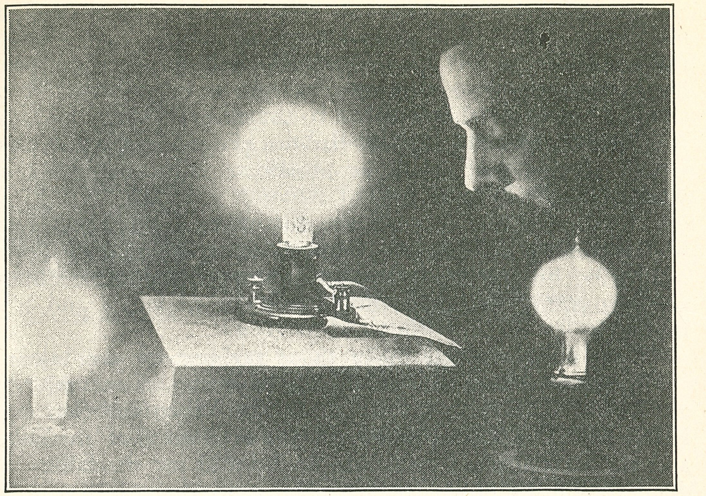
To this Mr. Edison may as justly reply: 'Grant that the lamp involves no discovery, that its elements are old; nevertheless, in combining old elements, I have produced a new product, an incandescent electric lamp which does what no other lamp has done; it will work and does work. Other men may have tried to do the same thing by the same means; they have failed; I have succeeded. Therefore, the lamp is fairly mine.'

If Mr. Edison's success is verified by time and use, the world will frankly accord to him the credit which is his due. But whether he is successful or not, the field is still open. It is not possible that there can be but one solution to so complex a problem. Such an event never yet occurred in the history of invention. Whatever Mr. Edison's success may prove to be, it should serve as an incentive to other workers in the same field to take heart and go on to like achievements; and the greater his success the greater the assurance that others can do likewise, or possibly better.

I have described some of the rival groups that Edison faced at the outset of 1880. One comprised the old chronic decriers who had always doubted his success. The second included men who had toiled in the same field and had lost; these informed the world that Edison had nothing new, that the same thing had been tried or done already by another.

The third, and the really dangerous group, held a combination of capitalists, patent pirates and technical experts who fully realized the value of Edison's discoveries. Their purpose was to imitate and outgeneral him by building a rival lamp with perhaps a change in the filament form which should avoid the horseshoe shape. No legal dodge or technicality was overlooked in their effort to capitalize on his patent or force him to come to terms. They even went so far as to employ detective agencies and spies to ferret out what they could at Menlo Park. They sought to lure away his best workmen.

The first public demonstration had furnished ample proof that Edison possessed the instrumentality of the coming illumination; its advantages fascinated nearly everyone. From a hygienic point of view it did not consume oxygen or vitiate the atmosphere; the amount of heat given off was surprisingly small. On the other hand a five-foot gas flame was said to consume as much oxygen as eight or nine persons and meanwhile diffused quantities of poisonous carbonic



The first photograph made with the Edison electric light. It was taken in the laboratory at Menlo Park in March, 1880. Batchelor is the subject.

acid gas and other fumes that tarnished metals and blackened ceilings and pictures.

The Edison lamp gave a steady light which unlike gas did not sizzle or flicker constantly. It was most convenient; it could be used in any position, and required no match; it could be turned on and off from a distance by the touch of a handy switch.

As he went forward towards his next great task, Edison prepared to continue searching for an even better filament material than cardboard. The various paper filament lamps at the laboratory and residences were subjected to life tests, and other lamp groups were kept under observation. The records of duration of life, loss of candle power and cause of eventual breakdown were noted and tabulated.

Materials whose structure seemed promising were tested as soon as found. The inventor examined them under the microscope both as raw materials and as finished carbon filaments; and he studied them after they had ceased to function as filaments, endeavoring to learn why they had failed. After each had finished its life test, it was broken open carefully and subjected to microscopic scrutiny.

An incident that happened about this time should be mentioned here. Edison had engaged several new men in the laboratory and the machine shop, and among them were loquacious ones who took great delight in explaining this or that to visitors without regard to the effect of their remarks. And yet work at Menlo Park had not progressed to the point where every detail could be broadcast indiscriminately to strangers.

The climax was reached one day when an assistant who was escorting a stranger round with academic mien and displaying his knowledge volubly, stopped before Batchelor as he was engaged in cutting out some filaments and said loudly:

'That's the way *we* make those carbons for the lamps.'

He lectured as if he were Edison in person. I was near by and saw that Batchelor was annoyed. When the two men had passed on he asked whether I had ever heard of 'the Duck and the Cabbage.' I had not; so he told me the fable. A duck swimming downstream passed a floating cabbage. As it came abreast the cabbage, the latter remarked: 'How we do swim!' With a laugh I replied that I was reminded of the three tailors of Tooley Street who sent a petition to their sovereign commencing: 'We, the people of England.'

The incident did not end there. On the following day Johnny Randolph came to the laboratory with a mischievous glitter in his eye and distributed to each worker a slip of paper, which he called an invitation from the 'Old Man' to the 'boys.'

The note was a masterpiece of chirography written by Edison himself with his electric pen. It ran as follows:

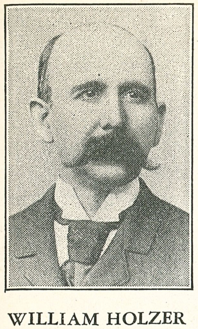
Menlo Park, February 19, 1880

Employes will treat visitors courteously, but under no circumstances will they leave their work or give information of any kind to visitors.

No information will be furnished except by myself or Messrs. Batchelor, Upton, Kruesi and Carman.

You will regard this as a positive order.

THOMAS A. EDISON



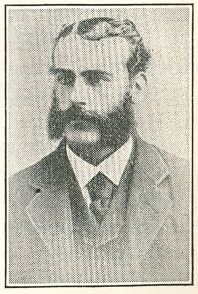
WILLIAM HOLZER

That note hangs today at the top of the stairs in the restored laboratory at Dearborn. It had its effect; for it rebuked the guilty one without being personal, and it also cured some others of the habit of inviting friends and relatives as if the laboratory were a museum instead of a place of research. Edison instructed Carman, who was bookkeeper and had a desk near the office building entrance, to admit only visitors who had credentials. Others were to be detained in the office and the person they sought was to be called there to interview them.

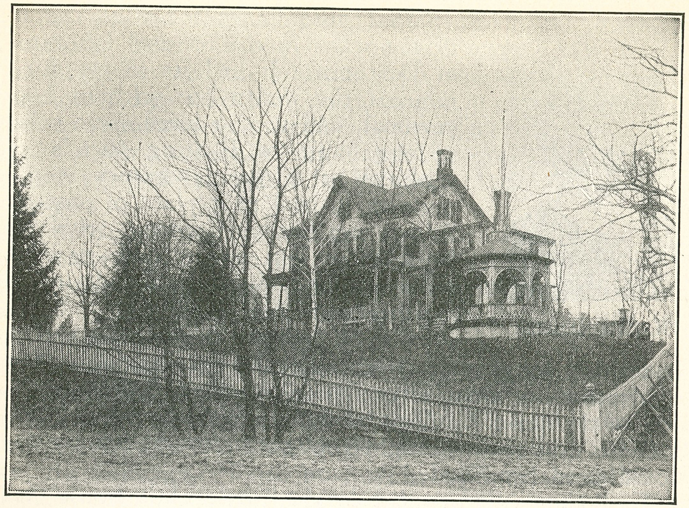
Mention has already been made in a preceding chapter of some of the newer members of our organization who came to us about that time or slightly earlier. Several other names should now be added.

To Boehm's department in the 'little glass house' was added, with the coming of the development period, William Holzer, a practical glass blower who had a shop in Philadelphia. He was engaged during the latter part of December, 1879, and entered into active service during the first week in January, 1880. As a glass blower, Holzer had all the refinement that Boehm possessed and in addition a practicality that was greatly needed in the glass work of the development period. He was instructed to study production in view of Edison's intention of starting a commercial lamp works in a few months.

Of course, rivalry soon sprang up between Holzer and Boehm; and as Holzer was a well-seasoned American, Boehm generally got the worst of it. Boehm deplored the corruption in method with which Holzer went to work to find practical means for producing stems and bulbs. Boehm saw the noble art of glass blowing degrading slowly to the crass mechanics of factory mass production. At Edison's suggestion, Holzer made annealers for stems and bulbs. He made iron forms in which bulbs as well as stems could be blown by a boy with a few hours' instruction.



JAMES HIPPLE



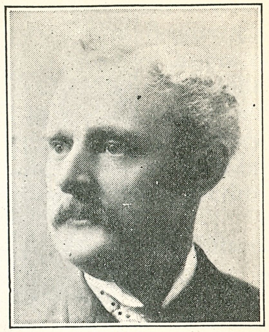
Edison's residence at Menlo Park.

Edison wanted a method that would consume less time than Boehm's and would hold the leads in the glass in better form than the tits, or trousers, which Boehm had employed in the paper lamp stem. With flat plyers of sheet iron Holzer was able to show Edison a method by which this could be done easily and quickly. Lamps today still retain this method. Holzer also introduced the cross-fire blow burners into the art of making the glass parts of lamps.

The newcomer was presently given a young helper by the name of James Hipple who in a few months acquired all the dexterity that was necessary for making the glass part of the lamp. The two men soon became pals. The good-natured Holzer, in fact, made friends with all and it was no surprise when he courted and married Miss Alice Stillwell, Mrs. Edison's sister. Holzer was made superintendent of the commercial lamp factory that presently was started and here his first great job was to break in youths from about the country in the art of glass blowing insofar as it related to the incandescent lamp.

Then there was Dr. Otto Moses. He was engaged to take charge of the library and to hunt up material in English, German and French books and magazines. He was also a

sort of link between Edison and foreign savants who came to Menlo Park; he was the 'sprechen sie Deutsch' and the 'parlez-vous Francais' interlocutor at the laboratory. He was serviceable later in lawsuits; for he had a general knowledge of science and theory which he could display more proficiently through his fluency of speech than in laboratory practice.



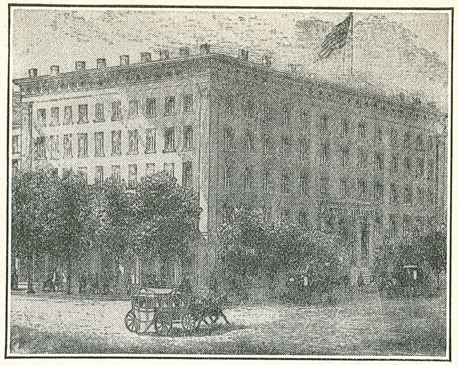
DR. OTTO MOSES

In the latter part of 1879, Mr. Isaacs was taken on as a photographer. This about completes the roster of the men who came to Menlo Park after Edison had invented the first practical lamp (with the thread filament), the first commercial lamp (with the paper horseshoe), the first incandescent dynamo, the meter, and so forth.

I desire to have it emphatically put on record that while Edison was toiling over the stupendous tasks of the creative period, he had but few men assisting him. Only when he had surmounted the obstacles and could see the commercial possibilities of the labors so successfully terminated did he resolve to press the development with all possible haste. To do this he had to engage the trained men and the recruits whom I have here described. Many of the newcomers were put on the lamp making pay roll in April, 1880, when manufacture of the lamp was commenced at the laboratory.

The statement has often been made that Edison had an army of trained men at his command with whose brains he managed to work all his wonders. Nothing could be farther from the truth. His was the sole directing mind both when those wonders were being created with a few men at his side and when they were passing through the development period with a large staff of trained workers and volunteers.

Wilson S. Howell once wrote to me: 'Your letter gave me much joy; it revealed to me that your judgment coincides with mine on the question of Mr. Edison's absolute independence of his assistants as far as brains and inventive ability were concerned. Claims to the contrary by light-headed, loose-tongued or envious men make only the impression on me that they do not tell the truth.'



Astor House, Broadway, Barclay and Vesey streets.

LIX. Life at Menlo Park

(PART ONE)

MENLO PARK was not a disagreeable spot in which to live, for its air and climate were pleasant. The laboratory was situated on a prominence commanding a view of the surrounding country with its verdant rolling lands. A half hour by rail took one to New York City. The summer winds brought refreshing breezes from the Atlantic, or from the woodlands in the North. Menlo Park had no town hall, school, or church, for it was a hamlet and its streets were dirt roads. Near the laboratory was a boardwalk, leading to the Edison home. It was in every way an ideal and secluded spot. That was why Edison moved here from Newark.

Edison's bookkeeper, William Carman, was said to have called his attention to the place, for the Carman family lived about a mile away toward Metuchen. The life and activity of the place centered in the laboratory; many of the men engaged there lived outside, at Newark, Rahway, or Metuchen.

The humdrum of the place, year in and year out, was perhaps tantalizing for the wives of the few married couples living there. Seldom did anything special happen to divert their feminine interest socially.

Generally on Saturday evenings there was a little exodus. Some went to Newark, New York City, New Brunswick, Jersey City or Philadelphia, returning in the wee hours of Sunday morning or perhaps on Monday. On Saturday nights when Mrs. Edison and her children left for a day-or-two-visit with relatives in Newark, Edison often came to the laboratory, only to find me there alone. I well remember one Saturday evening when I was there looking up some testing method described in my book on 'Electrical Testing.'

'What book are you reading there, Francis?' asked Edison.

'It's the book on testing that Mr. Lowrey gave me,' I answered.

'Let me see it.'

I handed him the book and as he leafed it he noticed the dedication, 'To Francis Jehl from his friend, G. P. Lowrey.'

Edison said, 'Go over to the library and get Kempe's latest edition—it's larger and has a blue cover.'

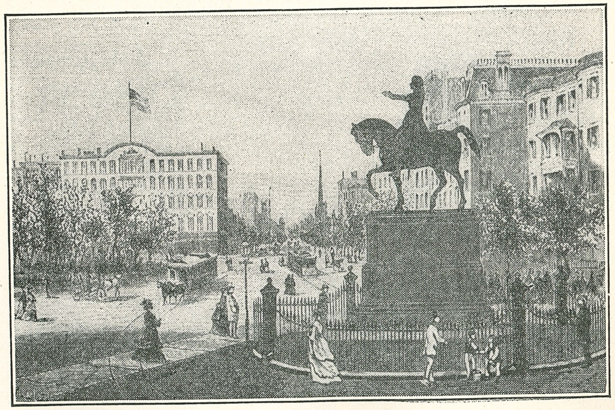
When I handed him the book he wrote the following lines:

'To Francis Jehl, my personal friend, Thomas A. Edison.'

I thanked him profusely for the great honor and he gesticulated as if to say, that is all right, there is nothing to it.

When he had looked at his watch he said, 'What do you say, Francis—let's go to New York.'

Of course I assented gladly, and we took the next train for the metropolis, arriving there about eleven o'clock.



Union Square.

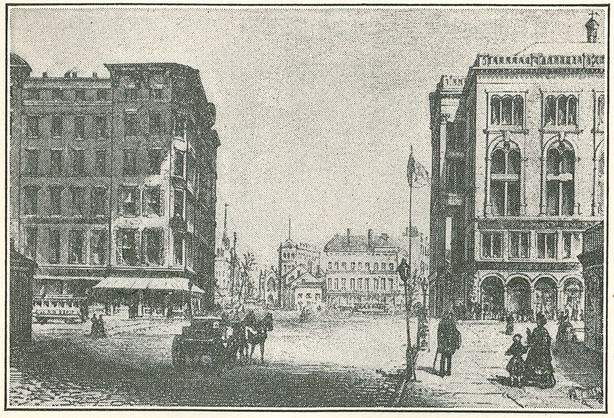
We sauntered from the ferry up Cortlandt Street to Broadway and passed the old Western Union Telegraph Building and St. Paul's. After taking a light refreshment at the old Astor House we strolled through City Hall Park into Chatham Street, continuing into the Bowery up to Cooper Union, into Fourth Avenue to 14th Street and Union Square. We went into the Union Square Theater where they were presenting Sheridan's 'The School for Scandal.' I may mention here that continuous shows were already popular, and certain show places gave performances until the early hours.

Fourteenth Street and Union Square were my old stamping grounds; I knew all the territory south to the Battery, having been born on Fourteenth Street. In describing this trip with Edison on that night, I picture a different New York from today.

After the show, Edison and I took the same route in going back.

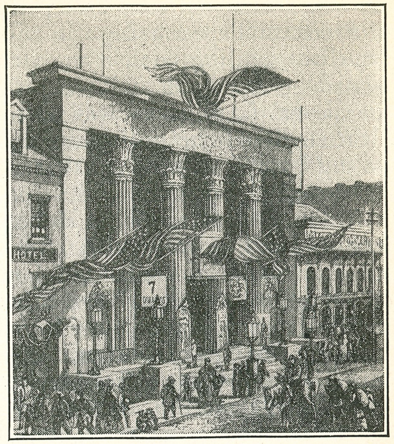
Several times we made Saturday night trips. One I particularly recollect was at Harry Minor's place to see some bantam sparring and other pugilistic exercises. Minor, it seemed, knew Edison. We had not been there long when he came up and said, 'Hello, Mr. Edison,' shook his hand warmly and conversed with him.

Once we went to Tony Pastor's, a place many old-timers



Bible House and Cooper Union, Eighth Street, corner of Fourth Avenue.

will no doubt remember. On another occasion we saw a 'blood and thunder' drama at the Old Bowery Theater.



Old Bowery Theater.

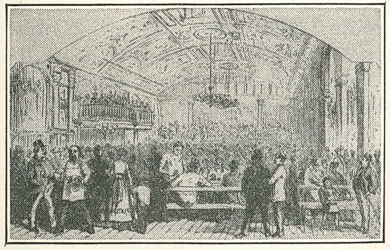
We also visited some of those large old-time music hall restaurants where the Germans congregated with their families.

On another Saturday evening we were walking up Broadway and in passing the Metropolitan Hotel on Broadway, corner of Prince Street, we stopped at one of the stores that had a sign 'To Let.' Into it a phrenologist, Professor Papbenheim, had moved temporarily. A barker at the door, who was trying to induce passers-by to enter, was extolling the fame of Professor Papbenheim, who had devoted his whole life to the subject of phrenology and whose services had been acquired by the crowned heads and royalty of Europe, also many of the eminent men of America, etc.

'Let's go in,' said Edison.

On entering, Edison paid half a dollar for both of us and we took our seats in the anteroom to await our turn.

Phrenology was said to be a science that connects the moral, intellectual and sensual dispositions of a person with the bumps on the cranium. The system of measuring these bumps was originated first by Dr. Franz Joseph Gail of Vienna, but the science soon found opposition and was declared unsound on physiological principles. Nevertheless, it has survived to this day.



Bowery Music Hall.

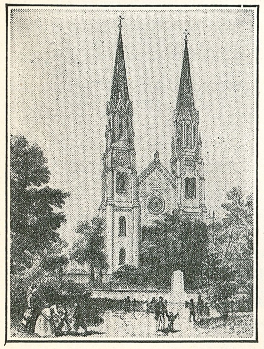
When Edison's turn came, he entered the inner sanctum of Professor Papbenheim. In about a quarter of an hour he came out smiling with a chart that explained all about the bumps on his head and what they indicated as regards to his mental faculties as well as other human manifestations. I then entered the professor's room, and he began working on my bumps, telling me that this or that bump was well developed or not so well developed, noting it on the chart.

I don't remember what the phrenologist said of Edison's bumps, but I do recall that after we went out Edison pulled his chart from his pocket and began studying it by the light of a window, laughing amusedly. Afterward he related the incident to others, and I saw it in print.

Early one Saturday night we went up the Bowery, entered Third Avenue and walked up to Eimer & Amend's Drug Store at Eighteenth Street. There Edison often bought exotic chemicals, assay equipment and glassware for the laboratory. Its apothecary shop was known far and wide for the purity of its drugs and conscientiousness in dispensing prescriptions.

Edison went into the store and ordered some chemicals. On leaving the place we walked to Sixteenth Street and toward Second Avenue. As we passed St. George's Church on the corner of Sixteenth Street and Rutherford Place, I related that I was confirmed there, and that our venerated rector was the Reverend Stephen H. Tyng, and later a Dr. Williams. I told him that J. P. Morgan, Robert Hoe and many of the wealthy families of New York City were members and busied themselves also with the girls and boys of the chapel the church had on Fourteenth Street where I attended. Robert Hoe, the manufacturer of printing presses, was my Sunday school teacher, and it was he who brought me to Porter, Lowrey, Loren and Stone, my early employers.

On special occasions we had to go to the church at Rutherford



St. George's Church, corner of Sixteenth Street and Rutherford Place.

Place. In summer we had many festival trips up the Hudson River to Tarrytown where Dr. Tyng had his summer home. In the winter there were other celebrations, especially at Christmas time. I can say that they did much for the children. Edison smiled when I told him that once at church I saw J. P. Morgan pass the plate to those he knew well in Wall Street, and that there was no rattling of coins when Morgan passed the plate.

Edison liked the quiet aspect of the Park with its fountain. The Park was closed nights but opened during the day, and it was there I often went as a boy to study school lessons. Edison and I then sauntered down Second Avenue and at Fourteenth Street turned toward First. I pointed out Grammar School No. 19 from which I had been graduated, and told him that our principals were Mrs. Sarah Buckwheat and William Smeaton. He smiled and said, 'That gives me an appetite. Let's go and get some buckwheat cakes and coffee.'

I showed him the house of an old school pal of mine who lived just opposite the school and whose father was a photographer. His name was Falk. My pal once told me that he was going to follow that trade, also. I mention this now, for this very school friend later became famous. Some of the best of Edison's photographic pictures were taken by him—Little Falk—who had a figure like Steinmetz.

As we barged back again—for Edison never hurried—we stopped at a place on Third Avenue and had our buckwheat cakes and coffee. Edison, I can say, always was fond of these Saturday night walks, especially in what was called the 'Tenderloin District' where there was always a throng of jolly people going to and fro. The fun was that he could go here without being recognized, and he enjoyed being incognito in these mobile 'grandstand' sights about that part of the city. We often tarried at street corners and watched the fakers duping the unsophisticated in supposed games of chance, vendors of bogus articles or quack medicines. Edison liked to observe how many different kinds of people it takes to make up this world. Perhaps in those Saturday night walks there may have remained some lingering reminder of those days when he was a telegraph operator restlessly going from one city to another in the Mid-West.

One Saturday night, while we were strolling up Broadway, Edison stopped near Houston or one of the adjoining streets and said, 'Let's see if we can get Bergmann.' At a little

three-story brick house, second from the Bowery, Edison stepped up and gave the iron knocker a few good bangs. Soon a head appeared at an upper window and cried out—'Where's the fire?' It was Bergmann, always in good humor.

I replied, 'It's Mr. Edison.'

Edison said, 'Get dressed and come down. We want to go somewhere and I want to speak to you on a matter.'

'All right,' answered Bergmann, who did not mind getting pulled out of bed at midnight. In fact, it appeared that this was not the first time that Edison had called on him at such an hour. Bergmann soon came down. 'Where do you want to go?'

'Any decent place where we can talk a little,' was the response.

We crossed the Bowery and went down to Second Avenue near Houston where Bergmann led us into a better class German restaurant. There in a large back room, still crowded with people, we seated ourselves. After a repast, Edison began to talk business with Bergmann while making sketches which Bergmann pocketed.

I may mention that all the places to which Edison took me during those various Saturday night tours were highly respectable and visited by the better class of citizens. What we today call old-fashioned congeniality still existed, and most stores, amusement places, and restaurants were still blended with old customs. Edison, like all of us, was human; he too had a longing now and then for a few hours of change and recreation. Usually, Menlo Park was a dull place on Saturday nights and if no pressing experiment or work was on, its inhabitants sought pleasure elsewhere. Those walks alone, for we never took a horsecar or omnibus, did Edison a great deal of good; the distance from the ferry to Union Square and back again was about seven miles. I never knew of Edison's taking any walking exercises about Menlo Park, although there were many nice rambles, especially in the direction of the rear of the laboratory. He always liked to be among people, to mix with them, to observe and study them from a stranger's standpoint just as a spectator watches a play. I am referring to the young Menlo Park-Edison. At times he liked the company of a few trusted friends where he was not in the spotlight and could, without any conventionalism, argue and talk at ease.

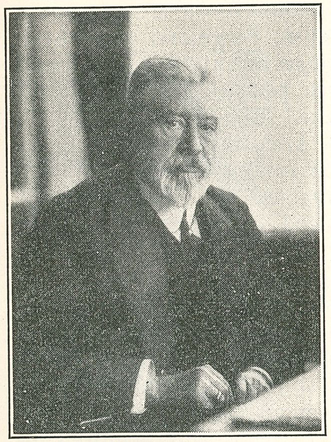
His attitude toward Bergmann was more than that of a

friend. Perhaps I may express it by saying the two were more like brothers who agreed with one another. Edison never entertained any doubt about the sincerity that cemented their friendship. Each needed the other at that critical period and no one else could have replaced Bergmann in the degree of excellency with which he played his great part. Everything he undertook went well; luck was always with him. Edison knew this, and I am sure that if Bergmann had been given the executive power over all the young Edison industries at the beginning, they would have succeeded financially, with or without outside help, and without losing control of them. This is not only my opinion. Edison himself once most explicitly stated the same idea of Bergmann. In *Dyer and Martin*, he declared:

'*Bergmann was a man of great executive ability and carried economy of manufacture to the limit. Among all the men I have had associated with me, he had the commercial instinct most highly developed.*'

In that statement, '*Among all the men I have had associated with me*,' Edison implied much.

Bergmann was as good an executive and organizer as he was mechanic; as a hustler he had no equal. These qualities drew Edison to him. His jovial temperament won friends everywhere. When Edison went to New York in 1881 and later, when Bergmann started his large works at 17th Street and Avenue B, Edison established a temporary laboratory at Bergmann's place, then after three years went to Harrison, and later West Orange. Not only did Edison know there were better facilities at Bergmann's factory, with help to work out practical experiments, but there was that feeling of mutual attraction that drew them together. It was a relaxation to be near Bergmann, and Edison, pressed and harassed by work, often sought a few hours' freedom at Bergmann's place.



SIGMUND BERGMANN

Edison could have installed his private laboratory from the first in his Harrison Lamp Works, the Goerck Street Machine Works, or elsewhere in New York City when engaged in working out some points of his system, but he knew that his most congenial harbor was the one in Avenue B.

In those days the high hats worn by men in all walks of life attracted no attention. Edison always donned a top hat whenever he left Menlo Park for the city, and when he lived in New York City he generally was decked with the 'stovepipe' or bowler style. Since his clothes were almost always dark, he was often shown marks of respect by the children of the East side, as he made his way to his laboratory at Bergmann's place. One day the climax was reached when a little 'shaver,' doffing his cap, approached Edison and said, 'Father Edwards, me mother, Mrs. Maloney, of No.——— Avenue A, bids me ax your Rivirince, since you be so oftin passin', to be kind enough to drop in on me grandmother, Mrs. Foley, who is clean gone with rumitism.'

Edison took care that this case of mistaken identity did not happen again.

Real old-timers of 14th Street will remember Father Edwards, the 'fighting priest,' as he was known on the East side. Many interesting tales are told of him and his work.

With Bergmann, Edison could argue freely, and if he thought it necessary, 'raise the dickens' in all its variegated old-time forms. He knew that it would never arouse resentment or hidden animosity. Likewise, Bergmann never hesitated to express his opinion (although not always in the best of English) when anything did not please him. That, too, was another reason why Edison liked 'The little Dutchman,' as some jealous ones called him. They thought themselves clever when referring to Bergmann in this manner.

I want to recall an incident mentioned in an earlier article, of the days when Bergmann worked at the bench back in Newark in 1870.

At that time Bergmann spoke very little English, for he had only been in this country a short time. Edison said of him, 'It doesn't matter if his tongue falters, his work speaks.' A bon mot occasionally quoted and said to have been uttered by Edison was: 'I got all the glory, and Bergmann the money.' Of course, it is but a piquant statement not to be considered seriously. What money Bergmann made was acquired in his own business. On the other hand, Edison controlled

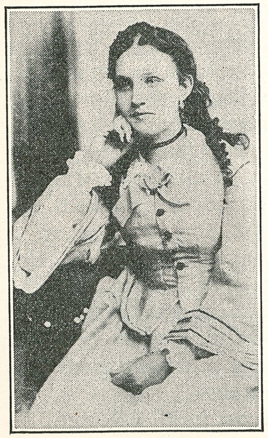
the various Edison industries and if some were not so profitable, it was not Bergmann's fault. Bergmann, a genius in business affairs, was more efficient in handling his money matters than Partner Edison. In this firm Edison contributed his ideas, while Bergmann put them into practical shape, manufactured and sold them.

These outings of Edison now and then to New York City were never undertaken at that period with any other member of Menlo Park, for quite obvious reasons. Long hours at the laboratory, and concentration on work for days at a time, ultimately necessitated a change of scenery to a place where he was unknown, where he could relax.

The married couples in the tiny social register of Menlo Park were Edison and his family, and those of Batchelor, Kruesi and Upton. Outsiders who did not belong to the Edisonian laboratory clan, or those that were engaged there in some other way, were formally but not intimately recognized. Some of my readers no doubt have lived in a garrison town and remember the social atmosphere of the place. At Menlo Park too was a tint of Main Street, and why not?

With the help of Mrs. Mary Edison, wife of the famed inventor, Edison really made Menlo Park the most renowned hamlet of the country. As we know, he came from Newark in the spring of 1876. While in Newark he had married the attractive and delightful Miss Mary Stillwell; she was indeed a gifted and charming young lady. They had three children, one daughter and two sons. Marion and Thomas Alva, Jr. were born in Newark, while William L. was born at Menlo Park a few days after his father invented the first practical incandescent lamp on October 21, 1879.

The Edison homestead was built on a plot of land 300 feet long by 150 feet wide; it was about 800 feet distant from the laboratory. The boardwalk, connecting the laboratory and the



Mary Stillwell prior to her marriage.

homestead, was later called Christie Street. Although the Edison residence was thus naturally considered the mecca of the place, formal festivities were very rare. The Edisons had a barn, horses, carriages and colored servants. Facing the house on one side was the old Post Road to Philadelphia, later called the Lincoln Highway. Under the circumstances, Mrs. Edison persuaded her unmarried sister, Miss Alice Stillwell, to come and live with her. Thus the edge of loneliness was driven from the Edison household while the master was at work in his laboratory up on the hill. To be the wife of the inventor had its dull loneliness as well as flattering bright side. She realized the comfort of knowing that her husband was only 800 feet away. Mrs. Edison bore with heroic patience and good sense the irregular hours of her husband; she did everything in her power to help him. She understood her position from the first day of her married life, even before becoming his wife. Being an intelligent woman, she knew that many other wives—of doctors, pharmacists, newspapermen, and others in different walks of life—were obliged to submit to similar sacrifices. She encouraged her huband and history owes to her more than silent gratitude for the care bestowed on him. A charitable soul, she helped many; few at that time knew with what bounty she was always ready to assist the needy.

MRS. THOMAS A. EDISON, 1872.

Their home was happy, and free from care. Mrs. Edison knew that her husband's mind must be free from petty worries or annoyances that he might work without interference from domestic source. She was his helpmate, interested in his work; confidence existed between them. She performed her duties as wife and mother in a most exemplary manner, gentle, sweet and patient. Thus, on the home side, Edison always came to the laboratory in a most cheerful spirit. In 1894 a writer described Mrs. Mary Edison:

'Mary E. Stillwell belonged to

MRS. EDISON, 1875.

that rare order of women who are prepared to admit the inevitable nature of certain existing conditions, and who do not exact as a primary concession to their new-fledged dignity the sacrifice of all premarital claims. By the exercise of this delicate tact, this wise effacement of self, Mrs. Edison's influence acquired a deeper force and subtlety, permeating the multiform strata of her husband's life, instead of constituting a personality apart, remote, chilly and exacting. She was greatly beloved by the men in Edison's employ, who to this day dwell admiringly upon her superior characteristics.'

At times Mrs. Edison and her sister would take the children for a carriage ride about the country, go shopping to Newark, or take in a matinee. Her distant relative at Menlo Park, Mrs. Sarah Jordan, kept the boarding house. Mrs. Jordan was a widow; her maiden name was Thomas. Edison assisted in establishing her as mistress of the first hostelry to be illuminated with his incandescent light.

MRS. SARAH JORDAN

Mrs. Edison was manifestly the first lady of Menlo Park, but her modesty never permitted her to reveal haughtiness; she always kept her sweet, mild disposition. Now and then the manor-lady gave an informal party in honor of

MARION EDISON—'Dot'—Edison's first born.

Marion, with the children of Menlo Park as guests. Merrymaking of all kinds took place, with plenty of refreshments at intervals. The affairs generally wound up with fireworks.

I have told how we at the laboratory called Edison's daughter Marion, 'Dot,' and Thomas A. Jr., 'Dash.' These names symbolize the two fundamental characters of the Morse telegraphic system. I have known Dot ever since, and am inclined to believe that had the donors of those sobriquets known the little maiden longer, they undoubtedly would have interchanged them. Marion should have been called 'Dash.' She certainly possessed in character and nature the dash of her father.

As a little girl at Menlo Park she bossed her brother Tom with the determined persistence of a virile Edison. She was, like her father, good-natured; she always handled Tommy with patience. When Dot was sent out to play and take care of Tommy, her mother was certain that nothing would happen to him. Dot often came to the laboratory and asked me for a glass dish or one of the small utensils, for she wanted to play with Tommy, making mud pies or something else.

Frequently, when she met her father, he asked, 'Well, what do you want now?' Shaking her body to and fro, she would smile as did he. Thrusting a hand into his pocket, he would pull out a few pennies and give them to her with a parting pat on the head. The two, Dot and Dash, would then hurry down to the Cornish grocery store near the stairs leading to the railroad depot and buy candy, no doubt for the sake of buying, for they had all they wanted at home. Park & Tilford sold not only general groceries to the Edison home, but also dainty luxuries. When Dot and her brother passed the boarding house,

Another picture of Marion Edison.

'Aunt Sally,' as they called her, frequently beckoned them in and treated them to a piece of pie or something good that she had just baked.

Wilson S. Howell told me of an amusing incident that once happened in the Menlo Park machine shop. Edison had repeatedly warned Junior that he must never, under any circumstances, go into the machine shop for he was afraid that something might happen to him. The machine shop, he told him, was no place for a child.

One day as Edison had entered the shop, his eagle eye saw Tommy Junior sneaking out the back door. Tommy Junior ran home while Edison, in the meanwhile, went to the telephone and told Mrs. Edison to give Tommy a spanking for having gone into the shop. Howell and Edison then went up to the second story balcony and from there saw Tommy innocently nearing the gate, where his mother was waiting for him.

What Edison and Howell saw then need not be described, but the impressions lasted and Tommy never could understand how his mother *at home* saw him *in the shop*.

Marion Edison (now Mrs. Oser) well remembers many of the informal parties that her mother gave at Menlo Park —especially those old-fashioned moonlight sleigh parties when the snow was deep and the air brisk and invigorating. She has never forgotten the time when the sleigh turned over and threw the party into a soft drift; what fun it was! She told me years later that she thought it was a put-up job. The guests to these parties were generally from Newark and Metuchen. Edison never participated, but he was happy to know that the folks at home were amusing themselves while he was interesting himself at the laboratory.

Marion was a great favorite of both her mother and father. One could not help liking her, for she was one of those little tomboy girls that fascinate you. In 1881 she was given a surprise lawn party, guests coming from Newark on an extra train. In the winter she was given another party. They had plenty of friends and acquaintances after Edison had attained success. It is surprising, how many friends and relatives one suddenly finds one has when worldly praise and success smile upon one.

Although Mrs. Edison never aspired to mount the social trapeze, yet she was fond of good company. She held her receptions and teas in town, while her Menlo Park home was

her castle. Even at Menlo Park many visitors 'crashed the Edison gate'; they were always received informally by Mrs. Edison; seldom was Edison present.

One Menlo Park lady who often came to the Edison home as an informal visitor was Mrs. Francis R. Upton, wife of Edison's mathematician and physicist. Francis Robbins Upton, to whom I have already referred in an earlier article, came to Edison at Menlo Park a few days after myself, in November, 1878. He, too, was recommended by Grosvenor P. Lowrey, a New Englander, who knew the Upton family that was connected with the philanthropist, Peabody. Upton was a scholar and a gentleman, brought up in the good New England fashion by a well-to-do family. He was educated both in this country and abroad, and possessed a mild, modest disposition combined with keen intelligence. His versatile knowledge of physics made him a most valuable assistant to Edison at that period.

While a bachelor, he was a star boarder at the Jordan house. In September, 1879, he took a vacation and went to Brunswick, Maine, to marry his college sweetheart, Miss Elizabeth F. Perry. She was said to be the fairest damsel of the little college town. If I recall correctly, Charles L. Clarke was present at the wedding ceremony, for he and Upton were once fellow students and chums.

I still remember when Upton brought his bride to Menlo Park. She was a fine, delicate, young lady, well educated and of a kind, pleasant personality. Occasionally the Uptons had visitors from New England, among them Upton's sister, Miss Sadie Upton. I recall her well. She was a smart, attractive young lady with a distinguished swing, and when she came once or twice to the laboratory, the boys forgot all their experimenting.

The Uptons occupied a fine old residence opposite the stairs leading down to the railroad station, and facing the old Post Road to Philadelphia. The homestead still stands; it has been kept ever since in such good order that it shows none of the ravages of time. In the summer of 1880, Upton took his young wife home to her parents in Brunswick, Maine. There their first child was born on August 24, 1880, and named for its mother, Elizabeth Fenno Upton.

While at Menlo Park, Mrs. Upton often attended Mrs. Edison's informal parties, since she was a sociable and agreeable person whose pleasant demureness made friends everywhere. Mrs. Edison frequently visited the Upton home; it seemed to me that these two were more friends than 'just neighbors.'

Among the other residents of Menlo Park was Charles Batchelor. It was rumored that when Edison moved to Menlo Park, he made a verbal agreement with Batchelor, giving him one-tenth interest of all profits. One can surmise that these profits were considerable when Edison made his lighting system a success, but while at Menlo Park, Batchelor and his family lived a quiet, restricted life.

He was constantly at Edison's side, putting into shape things that required skill and patience, and with which Edison then experimented. Batchelor and his family shared with the Kruesi's a double clapboard house that faced the Edison homestead on Christie Street. The Kruesi family lived in the same unpretentious manner as the Batchelors. I remember but little about these two families; to me it seemed they were bashful and too timid to mingle with the others. I would not say they were unsociable, for the wives of these two bright master mechanics had much to do in their own little respective apartments since there were children in each family. We must not forget that the financial status of Batchelor and Kruesi at that period was very modest. Their future expectations were great.

Upton's financial resources at Menlo Park were also not much. But he came from a wealthy family and was able to keep up a nice home with a maid and cook. Such were the conditions at Menlo Park.

Miss Alice Stillwell often came to visit us at the boarding house; there she first met William Holzer. Everyone liked Holzer as he was a sociable person, one who made friends wherever he went. At the supper table he generally caused a riot of laughter when relating some yarns that placed him ahead of all boarders. How nicely he coddled Mrs. Jordan, and in return received the best 'cut.' He really deserved this bit of partiality for he kept the gang together by ironing out any discord that appeared. When I say discord, I do not mean anything serious, only matters relating to meals. Sometimes when the boys did not like the menu on Fridays, because spinach and eggs predominated, they sang the old 'boarding house ditty:'

'There is a boarding house far, far away, etc.'

Then Mrs. Jordan would come in suddenly, with a sharp

determined mien on her face as if to say, 'What's all this rumpus?' She would be about to give us her piece of mind (and she could do it) when Holzer would step in and smooth over things.

In 1880 the visits of Miss Alice Stillwell to our boarding house seemed more frequent than those in 1879. Curiously, it was discovered later that her visits were about the time Holzer put in his appearance at the Jordan house. Not long afterward we found out that Holzer had his eye on Miss Alice and we thought that if he were successful in convincing Cupid of his ambition, future happiness and contentment were in store for both. Perhaps Mrs. Jordan discreetly did her part to assist. And so the two were joined in holy wedlock on December 2, 1881, by the Reverend James Cruickshanks at the Reformed Church in Metuchen, New Jersey. Mrs. Edison, who was then living in New York City, spent the following week-end at Menlo Park giving the young couple a grand reception at the Edison homestead. I may add that Miss Alice, like her sister, was a very attractive young lady with a mild and cheerful character that dispelled gloom wherever she was; two sisters were never so devoted to one another as were these.

Returning to the story of Mrs. Edison, I can state that the laboratory boys honored and respected her, not only because she was the wife of the inventor, but also because she was most considerate. She was endowed with a radiant personality that was bewitching. Whenever she came to the laboratory, she always brought smiles and pleasant greetings to all she met. Often she would stop and inquire what we were doing; she seemed interested. At other times when she came with Dot, she would sit down and tell Dot to go and hunt up father. When Dot found him, she would catch him by his coat ends and tell him that mother was waiting to take him home and that there was something good for supper.

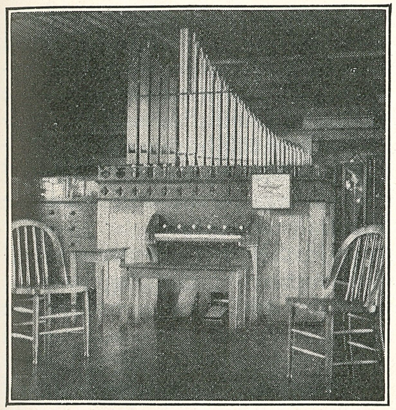
The soothing tranquillity of Edison's married life at Menlo Park contributed in helping him attain the heights of achievement and fame.

Edison generally had lunch and dinner at home, as did Batchelor, Upton, Kruesi and the others. I will say that the evening meals were not taken punctually but generally within reasonable time so as not to cause distress signals to be raised in the home kitchen. For the men in the machine

shop, quitting-time came when the steam whistle blew.

I do not wish to debunk the many stories told in thrilling words about the supernatural physical endurance displayed at Menlo Park where the men often worked with neither sleep nor food. The work was sometimes strenuous, but its character and surroundings made it a pleasure, and time did fly! We could have been mistaken for one family. Families don't usually go to bed after supper; they stay up until ten, eleven or perhaps twelve o'clock. That was about the same schedule we kept at the laboratory, and at times it happened to be an all-night session. When we were up very late, we were amply compensated the next day by enough sleep. As wise as Edison was in everything, he knew that relaxation and sleep were the best tonics for efficiency of mind and body; thus we kept a balance in our hours of working and sleeping, though the scheduled time was shifted now and then.

When occasionally we remained very late, Edison sent our night watchman down to the grocery store with instructions to awaken the keeper and purchase crackers, cheese, beverages, etc. These midnight lunches were most congenial; we sat in a circle and told tales; there was nothing Edison liked better than a good story or joke. Often Edison would relate a story; old-timers knew that he had a store of 'woppers,' and when he 'let loose,' he would set the boys roaring so hard with laughter that they would have to hold their sides. Edison never seemed to forget one.(1)



Organ as it has been restored in Menlo Park laboratory, Dearborn.

During the midnight lunches, Edison often went to the organ and played a tune in the 'pick and hunt' style. One of the boys who could play would give

(1) While visiting his old Menlo Park laboratory, which after half a century has been restored in all its original setting at Dearborn, Michigan, he 'fired some of his old guns' again; they were just as good as ever.

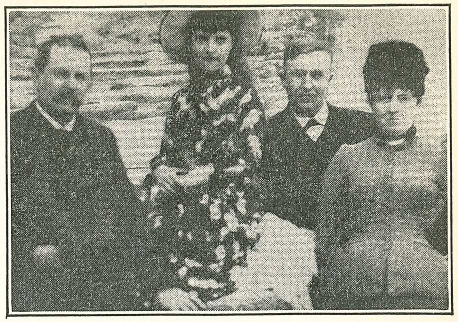
us some of those old tunes of yesterday, and all of us, including Edison, sang. Some of those old songs I still remember. There was 'Dolly Varden,' 'We Won't Go Home Till Morning,' 'Good Night Ladies,' 'Over the Hill to the Poorhouse,' 'Down in the Coal Mines,' 'Champagne Charley,' 'Grandfather's Clock,' 'Shoo Fly, Don't Bother Me,' etc.

Once we persuaded Boehm, the glass blower, to bring over his zither and play some of the old student songs of Germany so popular among his countrymen. He played the instrument well. Edison seemed to enjoy the music as much as anyone. Although Boehm was also a good yodeler, few of the boys could understand him. At night in his attic in the 'little glass house' where he kept bachelor's hall, he played the tunes of the Tyrolese or Bavarian mountaineers.

When the boys heard Boehm yodeling for the first time, they thought he was in great bodily distress, or that he was perhaps stricken suddenly with some sort of stomach ache. One of the boys asked me to mix some molasses and sulphur. 'What for?' I asked. He told me Boehm was groaning. 'Nay,' I said, 'he's just trying to sing like some of those mountain blokes in short leather breeches do in Europe.'

Well, that was enough for the boys. They set up a caterwauling that brought Boehm to his little attic window. His harsh censure in mixed German-American-English caused even more merriment. The boys teased him often, for although he was a fine glass blower he was so conscious of his own abilities that it was more than some could endure. Now and then when he was asleep, a few of the boys would gather rocks and at a given signal, throw them on the slanting roof of the little glass house. His bed was in the attic, and the awful noise would frighten him half to death.

At other times someone would take the 'corpse-reviver,' a powerful rattle attached to a soap box, press it against the wooden wall of the glass house and set it into action. The effect was that of dynamiting the shanty. On dark, calm nights, 'the ticker' was applied to a window of the glass house. This was simply a thread pendulum having a bit of iron at its end; it was attached to a long thread twenty or thirty yards away and operated from a hiding place. It produced a 'rapping and tapping' that would have made Poe's raven blush, and drove Boehm into a frenzy. The more angry he became, the more tricks were played on him. Of



Marion Edison in Florida with her father and Mr. and Mrs. Ezra T. Gilliland.

course, he complained to Edison about these happenings. And although Edison had solved many difficult problems in his life, he never managed to find who were the perpetrators of these pranks!

Since the fine art of the glass blowers made them hot and thirsty, those of the ancient order were traditionally anti-prohibitionists. The Menlo Park glass-blowing craft upheld the opinions of their brotherhood. Boehm was a German whose family commenced the glass-blowing art long before in their workshops at home. Boehm was fond of beer. When the scorching flames from the cross-fire gas jets were greatest, he would sometimes exclaim, 'Ein Konigreich fur ein stein!' and Holzer who understood German would reply, 'You said it, Ludwig.'

It was a firm belief among the blowers of glass that beer possessed virtues that would prevent tuberculosis. Perhaps you wonder how they managed to obtain it during the day. Some of the small lads living near Menlo Park always loitered about the glass house. Good-natured Holzer blew them trick swans and small glass vases. Later, when Holzer was sent to install the glass-blowing department of the first incandescent lamp factory at another part of Menlo Park, some of the boys received jobs, for he favored the lads who ran errands for him. Naturally the boys also received tips which they exchanged for candy.

Among these lads were two, Matthew Hankins and Benjamin Franklin Moffett. Young Hankins' father ran a dairy at Uniontown (now called Iselin) and worked for Edison, grading the bed for the electric railroad. Matthew helped his father in this work by driving a pair of mules. Benjamin's father, Charles William, was one of the first carpenters employed when Edison moved to Menlo Park.

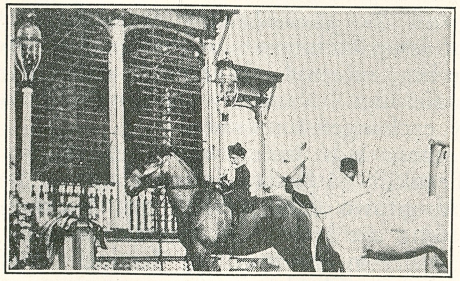
He lived near the little Edison electric railroad station, not far from the machine house, and helped in nearly all the wood construction work going on about the laboratory, machine shop and lamp factory. Later, he assisted at Harrison.

Hankins once wrote me he and Moffett used to 'chase the duck,' for Boehm at Menlo Park. McCoy, Hankins, Moffett, William Bogan and others became apprentices of Holzer; they learned the art of glass blowing at the lamp works in 1880. Hankins and Moffett became experts in glass blowing and later set up their own shops. Hankins was in Philadelphia, Pennsylvania. He blew several types of chemical, surgical and scientific glassware. Moffett erected his shop in the barn on his New Jersey farm. He manufactured miniature lamp bulbs and miscellaneous glassware. The old barn, changed to a glass-blowing shop, was the rendezvous of the old glass blowers who had learned their art either at Menlo Park or at the Harrison Edison Lamp Works.(2)

Another of Moffett's old friends, David K. Hickman, joined the laboratory force about 1880(3) and was placed at the mercury pumps by my assistant, George Hill. Later he was transferred to the Edison Lamp Works. Moffett and Hickman were lifelong friends. Recently Moffett's other daughter, Mrs. E. M. Palcanis, informed me that Hickman had passed away.

(2) John Olsen, glass expert of The Edison Institute in Dearborn ,Michigan, told me that years ago he visited the Moffett shop with Devoe, an old-time Edison glass blower. He added that one of Moffett's daughters, now Mrs. H. D. Goodwin, was a virtuoso on the cello, and the attraction of the Moffett home.

(3) A week after Hickman came to the laboratory William Bogan was employed at digging trenches for Wilson S. Howell's underground lines. Later Bogan was taken by Holzer in the lamp works.



Thomas A. Edison, Jr., on his riding horse at Menlo Park, New Jersey.

LX. Life at Menlo Park

(Concluded)

SOMETIMES during the evening exhibitions we were forced to stay up longer to entertain newspaper reporters who had missed the last train, and this delay made the work an all-night job. The scribes gave glowing accounts of how we worked day and night. The truth is that although they were with us during the night, I doubt if they knew how safe we were the next day in the arms of Morpheus.

Nine-tenths of those midnight suppers ended with the diners vanishing as soon as they had finished eating. Generally more dead-heads showed up at the late suppers than were supposed to be there. Machine shop boys who lived at the boarding house came up to the laboratory in the early evening; if they stayed they were invited to join us in the midnight lunch. When Edison left the laboratory in the evening to go home for supper, usually he did not return until ten or eleven o'clock; then he worked only for an hour or two. Little work was done when we had guests at the midnight repast, for the time was passed in reminiscing, telling stories or arguing.

Once Hussey, the Menlo Park postmaster, came up; knowing of his abilities as a tall-story-teller, the boys persuaded him to relate his life. He told us of the important positions he had held in various parts of the country and of the estimated time he had spent in each job. While Hussey was spinning off his tale, Edison was checking the total years. At last he asked Hussey, 'How long do you intend to live? You are already more than 140 years old.' Thus Hussey's biography was ended, and we all went home.

One of the contests in 'tall' stories was between Mackenzie and Hussey. Mackenzie, former agent and telegraph operator at Mt. Clemens, Michigan, has already been mentioned several times. With Mackenzie was his countryman, Davis, who kept the Menlo Park inn, known as 'The Lighthouse.' Both had an unlimited stock of yarns, fine jokes and stories given in delightful Scotch brogues. Old 'Mac,' as he was known, abetted by Davis, won the contest as easily as the

Marion Edison seated in front of her mother during Florida boat trip.
Edison is at right wearing straw hat.

'Meistersinger' in Wagner's opera. Hussey never forgot that night's whipping. He had been confident that his two official positions, that of postmaster and justice of peace, carried too much authority for him to lose.

As Edison's guest, Mackenzie's sojourn was unlimited. He boarded at The Lighthouse and came and went as he wished. He was a jolly good fellow whom the boys all liked. Often into our work he injected a spirit of merriment and frolic.

Mac was a good friend of Edison's father, Samuel Edison. The pair took long walks about Menlo Park and to Metuchen. 'Daddy Edison,' as the boys called him, was a hale, rugged gentleman of the old-time patriarchal type. He was born of the hearty set of pioneers who first surged westward from the mid-Atlantic coast. It was said that after Edison's mother died, the old gentleman remained near his son most of the time. 'Grandpa,' as Dotty and Junior called him, often took them for a walk or told them Indian stories to which they listened attentively.

On Saturday, August 9, 1884, Mrs. Mary Edison suddenly passed away, leaving Edison with his three little ones. It was a great shock to him; he suffered it with fortitude. Mrs. Edison had been ailing for some time with an obstinate form of neuralgia, yet she had never complained, conscientiously performing her duties as mother and wife. Menlo Park and the surrounding country mourned her passing; many recalled her kindnesses. All realized that her husband had lost a sympathetic companion, who had lived with him through those times he had ascended to fame.

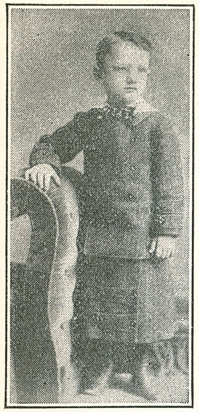
Her sister, Alice, with a sister's love and devotion, was constantly by her side. When the end had come, the physician told Edison, 'She is beyond human aid,' and folded her arms across her bosom and closed her eyes. On August 12 they carried her to her last resting place in Mt. Pleasant Cemetery at Newark. Many friends, including prominent men from the Edison company, came to pay their last token of respect and tribute.

Edison was desolate; the only one who could offer him real consolation was his venerable stand-by, Grosvenor P. Lowrey.

Grandmother Stillwell took care of the children while the Edison home was in Gramercy Park, New York City. During the latter months of 1885, the home was at the Hotel Normandie.

I have perhaps wandered from the subject of the strenuous work that we are on record as having done at Menlo Park. The work was strenuous, yet there was no forced action on it. When one sees in print that Edison 'would not go home for days' or 'he had not been home for two weeks,' it makes one wonder where the author got his information. Such stories, I know, are written—not to reflect upon Edison's intelligence, but more in the spirit of giving a 'tall' yarn to talk about.

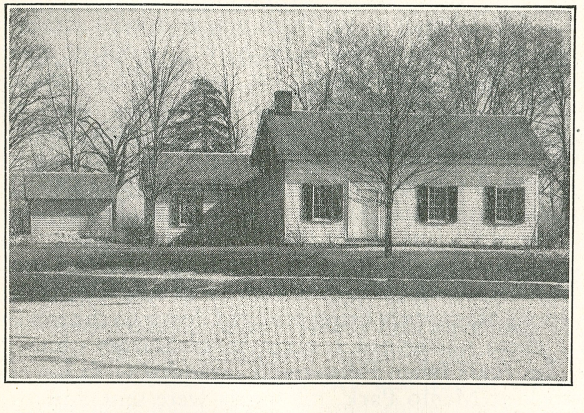
Of course, I cannot confirm anything that happened after Edison left Menlo Park, however, such things never happened while I was with him in the Menlo Park laboratory. Edison never tried to do the impossible. His wife, with her abundant common sense, knew when the limit was reached. Even the stories about his suppers being brought down to the laboratory and left there untouched contain more blarney than truth. During the years when Edison was occupied with his electric light work at Menlo Park, his meals were sent down to the laboratory not more than a dozen times. On frequent occa-



THOMAS A. EDISON, Jr.

sions it was Mrs. Edison's custom to prepare a cold plate topped with a big piece of pie which Edison's true American spirit relished. If newspapermen came to Menlo Park as Edison was preparing to go home to dinner, he would notify Mrs. Edison and she would send his supper to him. Clever Mrs. Edison knew what to do, and if the supper got cold, it was one scoop at least for the reporters that night. Edison was not seeking publicity, but often the newsmen from New York or elsewhere were assigned to Menlo Park for an 'interesting' story, and Edison always enjoyed helping others.

Perhaps you may have read about Edison extracting sunbeams from cucumbers. He was reading Dean Swift one day when several news reporters called. One scribe asked him if such a thing were possible. Edison smiled, for he knew they wanted a yarn, and replied that everything that seems reasonable may be possible. 'How so?' was the inquiry. 'The sunbeams,' replied Edison, 'strike the plants under certain conditions and their light, warmth and chemical actions promote the



Home of Samuel Edison in Vienna, Ontario. Now restored in Greenfield Village, Dearborn.

growth of the cucumber. Now suppose we could reverse the process, that is, by taking the finished cucumber and subject it to such actions that would undo and liberate again those actions that had developed it. Then we would obtain the sunbeams for practical use. The cucumbers in that case would be a storage battery for light and no doubt science would help the farmer raise a special kind for light production. The time will surely come in the future when chemists will produce many things by synthetic processes.'

'Why don't you take up the subject?' the reporters asked him. 'Perhaps I shall later on,' answered Edison. 'First,' he added, 'I want to show to the world that my electric light will do its work for a long while to come; there's no use burning up all your powder at once.'

The reporters often brought up questions on religion, faith and science. They delighted to get Edison arguing. He did not care to discuss all the intricacies that mark different opinions. He was thoroughly convinced that there has always existed a God who is the ruler and directive force for the whole celestial constellation extending into space without end. In his own words he once said:

'I tell you that no person can be brought into close contact with the mysteries of nature, or make a close study of chemistry, without being convinced that behind it all there is Supreme Intelligence. I am convinced of that, perhaps I may some time and I think that I could, demonstrate the existence of such Intelligence with the certainty of a demonstration in mathematics.'

Edison's *Supreme Intelligence* was his God; his Deity; his Lord; the Almighty; the Supreme Engineer and Chemist; the Infinite; the First Cause; the All-powerful; the Omnipotent, and all other appellatives man has termed the Supreme Being of each various creed. He never would wrestle with the abstractions set up by different kinds of dreamers or parties, and when asked what one should do, he answered, 'Everyone should do the best he can and trust to the Supreme Intelligence that rules the present and the future.'

Sometimes a scribe reported him as being an atheist, prompted by the hope of being followed by a retraction that would furnish more news copy. Edison never would repudiate such falsehoods in writing, and counseled others likewise. When asked how he imagined the appearance of his God, the Supreme Intelligence, he replied with a smile, 'I cannot

imagine the appearance of my Creator, for I am only a human; but I am convinced that the Supreme Intelligence which rules and directs all the worlds must certainly also be acclimated variantly to each world.'

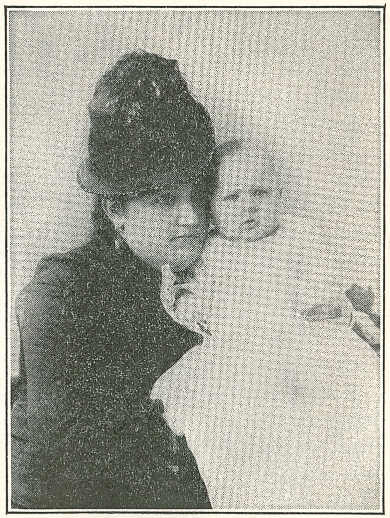
In this answer and construction one can see the reply of the scientific mind of Edison which places his God far beyond the thoughts of the mortals of this world. His Supreme Intelligence reigns in all kinds of conditions that exist in this and outside worlds, and admits thus of no human personification.

He saw his God everywhere, in nature, in the atoms and their combinations, in electricity and magnetism, in mechanics as well as in the laws that we know dominate everything, stable or unstable. At some of the night luncheons as we gathered about him and discussed serious matters, this question would often come up and was always mingled with earnestness, as well as unconformity. Edison himself never deviated from his belief of the Supreme Intelligence.

His very personality, as we knew the young man of Menlo Park, possessed those attributes that scintillated with goodness. If we may use modern slang, he was in every sense of the word, 'a square shooter.' And because he was such 'a square shooter,' modest and confiding, he was often imposed upon by others with greedy motives.

In one of those night discussions at the Menlo Park laboratory, the question came up regarding the Ten Commandments.

Edison considered the Ten Commandments as the quintessence of all just laws ever written by man. They came gradually into use when



Mrs. Thomas A. Edison and William L., her youngest child.

man's gregarious instincts first began to form communities. The Ten Commandments, Edison believed, were the products of divine inspiration not only to mankind but to all that was put into existence by the Supreme. I can also state most positively that Edison never criticized any religion or faith, not even those of the jungle folks. He said that men, according to their general cultural standing, have different views and thus worship in different ways. Edison also recognized the importance of institutions that strive to bring spiritual thought and consolation to mankind. Edison always honored the great teachings of those masters of different creeds whose tenets have brought comfort to the body and soul of fellow creatures.

Edison was often misquoted on the subject of belief. Frequently the newsmen would misconstrue his ideas.

With Edison appeared the dawn of practical possibilities in electricity. He developed a progressive and industrial science. He was never pedantic nor narrow-minded in what he did, as he gave the world basic facts upon which mathematicians and scientists formulated and based their equations.

Now and then newspapers would report that Edison thought mathematicians and scientists generally were not so productive to mankind as self-made men. When he told a reporter that if he needed one he could hire a mathematician, he meant nothing by it, for he knew that mathematicians work with a fine set of tools that require expert manipulation. He knew that mathematicians as well as scientists have given the world valuable data that practical men have employed for practical purposes. I well remember how often he praised mathematicians and scientists. If he was said to make discriminations between qualified and unqualified ones, he was doubtlessly misquoted.

From all I have mentioned, it will be seen that the social conditions at Menlo Park were tinged with a mild Bohemianism and the men had really no complaint. Of course, some will say that it all happened in the good old days. The few old-timers still living will confirm that they never saw Edison in a hurry or out of breath, and yet he accomplished fantastic realities in a short time.

The young inventor was human and considerate and he possessed a character and traits that made him a leader among his fellows. He was a thinker, with ability to probe into the mysteries of the future and adapt them to man's use.

There is a curious matter upon which no mention has yet been made. That is the fact that the seer of Menlo Park did most of his thinking at home. He would often come to the laboratory from his home in the morning, fresh and jaunty, and say, 'I was thinking about this or that last night, and now let us try it.' One can see many reasons for this, for in the seclusion of his room at home, his brain could function untrammeled. Even on his way to the laboratory in the morning he would say, 'While coming up I got this idea.'

His brain was always active. When an idea came to him, he followed its lead mentally; then worked it out experimentally. Even at the laboratory he would lie down sometimes to think out ways for further developing an experiment already in progress.

Much of his time was spent in seeing that the work was properly executed. Of course, the principal experiments were carried on by him personally, and when he arrived at a promising stage he intrusted the job to others. However, he watched closely all progress.

I must not forget to mention that he was very fond of his cigar; he was an inveterate smoker. In the morning he came to the laboratory with a cigar in his mouth and continued to smoke during the entire day. He never smoked his cigars down but generally consumed them to a little less than half their original length. He chewed the remainder. It was interesting to watch him light a fresh cigar. How he would relish the first puffs as he blew the smoke up into the air! His cigar was somewhat an assistant, silent, but helping him in his imaginary expeditions to stimulate paths of thought. He also chewed tobacco; frequently, he would take a tinfoil-covered packet from his coat pocket, gracefully extract a quid, and with a professional swing put it into his mouth. I was introduced to the weed in the Menlo Park laboratory; I still remember the sad effects of my first cigar and the hilarity it created among the boys.

MRS. EDISON in 1881.

It will be seen that the men of Menlo Park, especially those engaged by Edison, had little cause to suffer the doldrums to which perhaps some of the women may have been subjected. The laboratory and machine shop were congenial places in which to work, with a man like Edison for a master, friend and adviser.

The work was instructively exhilarating and fascinating. All liked the chief, especially because of his youth and modesty. When he found one in whom he could trust, he used him as a confidant. He never put himself forward as an exalted figure. In no way did he boast of being infallible. His manner created a profound respect for him from his employes and he mingled with them in an intimate manner. He possessed an irresistible personal magnetism; no one ever felt the least bit uncomfortable or abashed in his presence. Since he possessed these qualities, it is evident that he was never harsh or irritable in dealing with his men. If something happened that apparently caused annoyance, he took it in such a good-natured way that we could not help smiling at his displeasure.

Edison's work at Menlo Park was quality work. But when he went with the boys to New York City to introduce his system commercially, all soon realized what quality and quantity work combined meant; how different it was from pure experimenting!

Edison was a kind-hearted man; with compassion for his fellowmen who were less fortunate. He was always ready to extend a willing hand to the young. He probably remembered the many difficulties he had to surmount as a young man. He remembered the galling stings he had to bear at times when the odds seemed against him. He knew well what it was to be cross-pathed by others who had no consideration. He also knew what a helping act could mean in time of necessity.

I remember an incident told me by Wilson S. Howell. In 1880 an assistant of Edison was carrying out some work of an experimental nature. He was given a lad to help in coarser parts of the work, who had come from a farm and was now making his start in life. He was simple and willing with good manners, but not apt at carrying out instructions, and as a result things often went wrong. After several admonitions his patience was exhausted, and he asked Edison to discharge the boy. Edison eyed the lad, and good-naturedly

presented him with another opportunity of a different nature. The boy was sent to Kruesi, under whose management he did well and soon became a useful helper. Later, I was told, he became a full-fledged mechanic.

Such incidents were not infrequent ones. I recall distinctly when I was taken ill in 1879, the nature of my ailment being unknown to me. Edison soon noticed that something was wrong and he was not long in learning exactly what was my trouble. It was malaria fever. 'You must stop work right away, Francis, and have a change of air for a few weeks,' he told me. He went to the office and returned in a short time with a wad of United States bills, together with a package of quinine, both of which he put into my hands saying, 'You must leave Menlo Park today and take the first train to Asbury Park by the ocean.'

A few weeks later I wrote a letter to Judge John K. Porter. (Grosvenor P. Lowrey, and Porter were the senior heads of the law firm of Porter, Lowrey, Soren and Stone.) I mentioned Mr. Edison's kindness to me. The judge answered as follows:

Adirondacks, New York

Your letter reached me here and I am glad to find that you are so much pleased with being in the employment of Mr. Edison.

He is not only a man of extraordinary genius, but he has a warm and generous heart. Make yourself as useful to him as you can, and he will appreciate your fidelity, and prove a kind and lasting friend.

Persevere, and I have no doubt you will be successful.

Your friend,
John K. Porter.

When Edison was attempting to make a more efficient thermopile than existed, he tried everything imaginable; he always had several 'irons in the fire' as a bit of recreation. The attempt to generate current directly from heat for practical purposes was a luring problem. As you know, the thermopile consists of two different kinds of metal or alloys connected at one end and subjected to heat. If the other ends are connected to a galvanometer, a deflection will be observed.

Last resting place of Mary Stillwell Edison, Newark.

Edison assigned a man to make a few thousand kinds of alloys, varying in proportion of mixture with different chemicals. It was Kruesi's job to plane the thermopiles down to neat bars, all of the same size. When they were brought to me, I tested them with the Thomson reflecting galvanometer, while I heated their junction with a Bunsen burner. Their resistance generally was high in comparison to that of a single wet battery, and their electromotive force was generally very low—a fraction of the e. m. f. of a simple Daniel wet cell.

One day while making such a test, I made a very interesting discovery, described as follows in the words of Wilson S. Howell:

'Mr. Edison's judgment and prevision were generally so excellent, so accurate, that a miss was rather disturbing to him. After he had carefully thought out a plan, he was not always meekly patient if the test or demonstration upset his calculations. He would not hesitate to question a test and request its repetition, carefully going over the methods and conditions of the tests to find a flaw or error which would upset the conclusions.

'Mr. Jehl was asked one day to make a test for Mr. Edison, the results of which were very disappointing. The test was repeated but still the figures were not pleasing. Each step in the test was questioned and carefully gone over by the great inventor, but its accuracy could not be shaken. As a last resort, Mr. Edison asked Mr. Jehl if he had made any allowance for the friction against the air of the light beam from the mirror of the Thomson Reflecting Galvanometer used in the tests. Jehl acknowledged he had not but would calculate it at once if Mr. Edison would give him the constant.'

In such cases, when Edison joked he gave a broad smile, put his left hand behind his neck, scratched his right ear and marched away.

I remember once when Kruesi brought in a thermopile whose alloy contained much sulphur; it was polished so brightly that it resembled gold. Edison, Upton, Batchelor and several others were seated about my testing table when

Kruesi brought it. Edison took the bar from Kruesi, weighed it up and down in his hand, and said to Upton, 'We have it this time. Our worries will soon be over!' He winked to Batchelor and Upton who understood at once that a joke was coming. Kruesi appeared perplexed and inquisitive; before he could utter a word, Edison said, 'I suppose the best thing to do now is to close up the whole "shebang," shop and laboratory.'

Kruesi could endure it no longer. 'What is it Mr. Edison?' he managed to ask in his excitement.

'Didn't Batch tell you?' Edison replied in astonishment.

'No,' answered the impatient Kruesi.

'You've been planning it and handling it all along and you never thought what you had in your hands, Kruesi; why, it's solid gold,' Edison replied.

'Gold!' blurted out the bewildered Kruesi.

'Yes,' replied Edison, 'Dr. Haid has tested its specific gravity and given it the acid test. It's pure gold and we can make it by the ton; our worries are over, Kruesi. We don't need the light now.'

The boys, with some difficulty, kept up a serious mien while Kruesi was dumbfounded.

'Don't tell anyone about it, Kruesi, it's a secret and only those here are in on it,' Edison said.

When Kruesi promised that he would never say a word about it to anyone, one of the boys, who was unable to restrain himself, laughed aloud; the whole crowd joined in while honest John realized Edison was playing one of his jokes.

Another time I was working at the testing table when Edison came along with an element of a thermopile he wished me to test. Martin Force, who was standing by the table, watched me adjusting the reflecting galvanometer to its proper position for the test. I usually removed keys, knives or anything of iron from my pockets

MARION EDISON OSER

and laid them aside. When the instrument was delicately adjusted, a small piece of moving iron would produce disturbing effects. As I began to test the thermo-element, Edison saw that the beam of light sometimes shot upward on the scale, indicating an abnormal increase of tension.

Perhaps Edison had at last struck a bonanza element, approaching the proper composition of the element's alloy. Possibly this special alloy required only minor changes in its composition to make it a thermopile of unprecedented voltage.

Edison closely watched the scale of the galvanometer; suddenly he remarked, 'Say, Francis, have you an iron watch?'

'Iron watch?' I replied with a tone of injured dignity, 'mine is of silver and it was given to me by my father.'

With a mischievous smile, Martin Force took out his watch and began swinging it on its chain, while the spot of light on the scale danced in unison, thus explaining the galvanometer. After another test we found that the thermo-element was nothing unusual and consigned it to the junk pile.

Once, while I was at the pump extracting air from an experimental lamp, someone asked if it were not possible to elevate the lamps above the atmospheric line where vacuum reigns and where the lamps could be sealed.

'Good idea,' said Edison. 'We will take a patent on it.'

'How will we seal them if we have no air for the blow pipes,' another one asked.

'That's always the way!' Edison complained, 'No sooner does one man strike a brilliant idea than somebody else comes along to show why it is impractical. There's no chance today for bright boys with good ideas.'

Many men in those days thought they had inventive blood in their veins. Some came to Menlo Park to offer suggestions and ideas, while still others brought inventions. Edison's career incited many who possessed an exalted opinion of their own abilities. In him they saw what a self-taught man could attain, although they never realized that it takes more than self-tuition to lead a man to success. Successful men are a special species. They don't ask to accumulate facts like a dead book; they exert strenuous efforts to utilize facts for a purpose.

Perpetual motion cranks often dropped in. It seemed more difficult to get rid of these deluded men than any other kind. Some became very excited when Edison or Upton tried

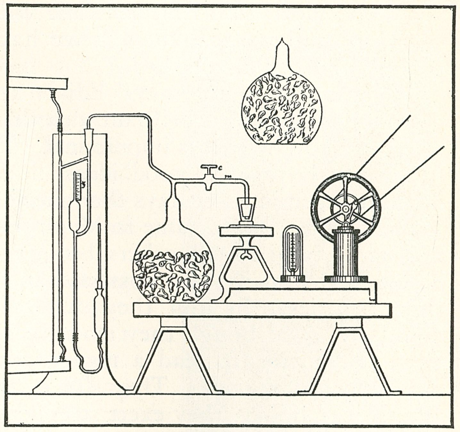
to explain to them that 'you can't get something from nothing.' One fellow to whom Upton tried to elucidate the laws of the conservation of energy and its transformation really became abusive; we had to step in and put him out of the laboratory.

Interesting experiments were made with the Geissler tubes during 1879.

Gassiot first investigated the luminous discharge in rarefied gases. Geissler, expert glass blower of the University of Bonn, Germany, adapted and commercialized that idea in a unique manner. In fact, Geissler's interesting additions to his tube collection made him so famous that the title of 'doctor' was conferred upon him. The neon light of today is simply the Geissler-Gassiot tube of yesterday. Neon, argon and helium gases did not yet figure in the chemistry of those days.(1)

It was Edison's idea to try all kinds of gaseous mixtures at different stages of vacuum. He found that when the rarefaction of the gas was varied, some gases changed in color, depending upon their densities. He wished to determine whether it was possible to obtain a better illumination for lighting purposes. Dr. Haid, our chemist, prepared gaseous combinations, while Boehm blew the glass tube containers of different forms. Edison experimented with the Gassiot tube.

This tube was of flat glass, spiral shaped, having six or seven turns, and containing rarefied carbonic acid gas. When the current from an induction coil was applied



Drawing from Patent No. 248,431, device for preserving fruit, and other perishables.

(1) Boehm, our glass blower, was once an apprentice at the Geissler shop in Bonn, Germany.

to the tube, it gave a pale white light. Edison's interest came from the fact that the light given by the tubes was literally cool light of the luminous intensity at which they were operated. Could he succeed in making the light mellow and of greater intensity, it would possess many possible advantages. These experiments, like those of the thermopile, were conducted more on a preliminary basis and essentially to see what the chances were for continuing the work more extensively. The New York *Herald*, in its famous issue of December 21, 1879, mentioned this way of producing light.

In the early years of 1900, vacuum tube lighting was undertaken by D. Macfarlane Moore, who succeeded in making tubes of twenty-foot length or more. He made them glow by means of high-tension alternating current and managed to obtain an efficiency of about 0.6 to 1.4 watts per candle, depending upon the gas employed.

Thus we see that there were many different ways of making light. There still are unexplored fields of economical light sources for a future 'Edison' to discover. What the future will bring we do not know. Possibly some day we may produce light that does not depend on high temperature—perhaps cold light.

J. A. Fleming says that with the half-watt tungsten lamp we may produce 1,500 candle power with one horsepower. If we can penetrate the firefly's secret, we may be able to produce 5,000 or possibly 10,000 candle power per horsepower.

Another experiment which served as short diversion from the important work, was an attempt to discover a means of preserving perishable food for transportation.

During the latter part of 1880 Edison's agent in London, England, Colonel George E. Gouraud, paid us a visit. He was a jolly chap; Edison was pleased to see his old friend again. Their friendship dated from 1873, as mentioned in Volume One.(2)

Gouraud and Edison were sitting by the old telegraph table at the front of the laboratory when the latter mentioned that he was going to try some experiments in preserving fruit.

'Do you think you can find a way to send fresh meat to England?' asked the Colonel.

'I'll try an idea that I have. Perhaps it will work,' replied Edison. 'By the way, when do you intend to sail back, Colonel?'

(2) Volume One, pp. 58, 167.

'I think I'll sail next week,' he replied.

'Well, let me know the exact date and I will have a fine porterhouse steak ready for you, sealed in a glass container,' continued Edison.

A few days before Gouraud sailed, Edison brought to the laboratory a fine steak that made us smack our lips.

Calling Boehm, Edison instructed him regarding the large glass tube container to be made with a stem, by which it could be connected with the Geissler-Sprengel vacuum pump.

When Boehm had completed the container, I put it on the pump to expel the air, a most difficult job, as the moisture and other gases were plentiful.

'Look,' I said to Edison, 'the phosphoric anhydride is "sweating" for all it's worth; we'll never get a vacuum on it. How would it be to sizzle the steak with the alcohol lamp from the outside, just to drive out the occluded gases and moisture?'

Edison smiled and told me to keep on pumping. After five hours we stopped the pump and sealed the container in which the steak was. Edison intrusted Hughes, our buyer, to take it to Colonel Gouraud at his hotel.

The steak reached London all right, but the reports varied regarding its sanitary condition and food value. One report hinted that the Colonel generously invited young Sammy Insull, who was engaged in his office, as guest, while the Colonel himself pleaded a dietary excuse. Whatever the case may have been, that porterhouse steak caused sufficient interest for the newspapers to write up the incident. Later on Edison made a patent application December 11, 1880; the patent for preserving fruits and other victuals was granted October 18, 1881.

I remember another amusing incident that happened when Howell entertained a group of visitors from his home town, New Brunswick. While he was explaining the testing table, a young lady inquired about the Leyden jars. Howell explained that they were used in storing static electricity. Interested, she edged toward Howell who demonstrated to her how the jar was charged by a friction machine. He 'loaded' the jars with electricity and then instructed the party to take each other's hands, chain or link-like. Howell was pressing one of the interested girl's hands and pretending to touch the Leyden jar knob with his other. He asked the girl and the others in the party if they felt any electricity

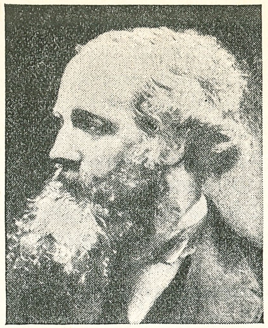
passing through them. The maiden blushed and said that she seemed to sense a peculiar sensation, but that it did not seem strong. She did not know electricity could feel so pleasant. When Howell actually touched the knob of the jar, the group wriggled and shrieked loudly. They all looked a bit embarrassed for a moment, but soon they were laughing and chatting about the shock of electricity they had received.

Dr. Moses was, I believe, a perfect guide about the laboratory. He was a Ph. D.; speaking came natural to him. He was always faultlessly dressed; his studied manners were evident when he addressed a party. He was a well-read man —and most pleasant to deal with. He could speak French and German. Edison generally favored Moses with parties or visitors from foreign countries, as well as those who were talkative and inclined to ask many detailed questions.

Once Edison remarked that he had passed over to Moses a visitor who talked continuously without pausing for breath. 'I wonder who will get the best of it, Moses or Mr. Blank,' Edison remarked.

Searching for articles and obtaining data from the library were Moses' chief duties at Menlo Park. His life job should have been that of a lecturer.

MRS. WILLIAM HOLZER
Sister-in-law of Edison. Before her marriage she was Alice Stillwell.



JAMES CLERK MAXWELL

LXI. Comments From Europe

EDISON'S great inventions as incorporated in his new system of electrical energy distribution provided American newspapers, journals and magazines of that period with plenty of excitement. Foreign papers were not behind in sensational reports, either. Authorities and scientists were interviewed and questioned everywhere. Telegraphic inquiries and explanations were demanded. The first public demonstration of the light at Menlo Park in 1879 had indeed created world-wide furor.

Griffin at the office was put to great exertion making clippings from newspapers and journals that were sent to Menlo Park from friends as well as anonymously. Of course we read them all, the favorable as well as the unfavorable, debating often on the inconsistencies presented in many of the criticisms.

The magazine *Engineering* of London, one of the greatest mechanical journals in the world, published the following in its issue of January 9, 1880:

> Almost the whole civilized world would appear to be waiting with feverish anxiety for fuller details and confirmation of Professor Edison's latest discovery in electric lighting. If he has indeed arrived at the solution claimed and has produced a domestic light free from the disadvantages hitherto attendant upon electric illumination and those which are inseparable from gas; a light at the same time cheap in production, entirely under control, capable of regulation, and requiring no special management; it is certain that for the first time since the problem of electric lighting has been studied, gas has found a dangerous rival.

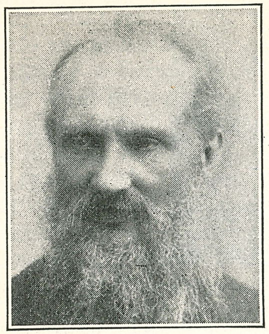
The *Electrician* of London remarked, 'We do not doubt that his cardboard lamp will also prove a failure' . . . 'We must credit Mr. Edison with energy and ingenuity, but as yet we fail to see that he has solved the problem of the electric light.' From the *Engineering & Mining Journal* is quoted the following: 'At the same time, we have a firm faith in the ultimate economic success of the electric light for general use, and we have also a very high opinion of Mr. Edison's ingenuity' . . . 'While not wishing to discourage Mr. Edison or his friends, nor to undervalue the service he is doing to the ultimate demonstration of the practicability of the electric light, we are of the opinion that it will be as well to suspend judgment for the present, until at least the latest plan of Mr. Edison has had a few days trial in practice. The issuing of periodical pronunciamentos from Menlo Park may possibly record substantial scientific triumphs.' Thus did the English press receive and give opinions regarding the New York *Herald* article of December 21, 1879.

Well-known scientists of those days also voiced their opinions variously. Proctor, the eminent English astronomer, expressed admiration for the American wizard's feat accomplished within the charmed circle of Menlo Park. After reading the *Herald* article he said, 'If the light and apparatus that produce it are what they are said to be—and I have great faith in the inventor's representations—I believe that a flattering advance has been made in the art of illumination.' When asked whether this new invention of Edison's would be successful in practice, Professor Proctor answered with a smile, 'I fancy that the inventor of the phonograph is equal to almost anything. I was the first to recognize the value of his contributions to scientific discovery. In fact, my faith in Edison subjected me to ridicule once or twice.' Professor Proctor had nothing but high praise for Edison's abilities.

W. Crookes, the inventor of the radiometer whose able experiments on radiant matter created much excitement in the scientific world, said: 'I do not believe that the "horse-shoe" of Mr. Edison can last for any length of time, because it is impossible to extract the whole air from the tubes and there must always remain a certain quantity in them.'

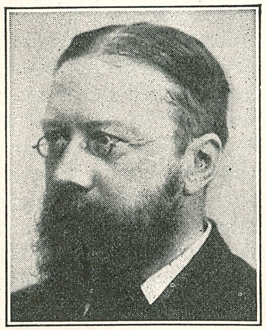
Most of the French savants believed in Edison's wonderful lamp. Wilfrid de Fonvielle, the editor of *L'Electricite*, when questioned about the discovery, said: 'The illustrious inventor whom the discovery of the phonograph has immor-

English Contemporaries of Edison

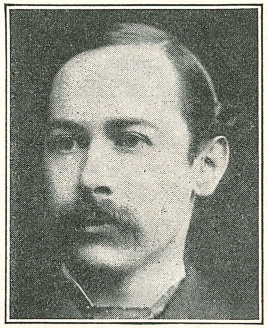


LORD KELVIN
(Sir William Thomson)

SIR WILLIAM CROOKES



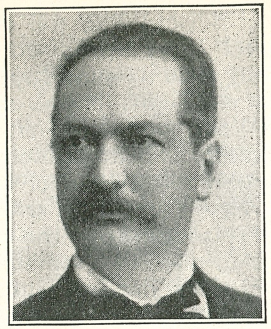
SIR W. H. PREECE



PROF. SYLVANUS THOMPSON

talized and whose reputation is now solidly established can brave the jealousy of the invidious in both hemispheres; for his work will be appreciated in future ages when the names of his latest obscure critics of the present day will have been long buried in eternal oblivion.' De Fonvielle belabored the academicians roundly. 'We can understand,' said he, 'that they should be indignant at the Palais de l'Institute that a newsboy should take it into his head to discover phenomena that have escaped all the decorated academicians. It is consoling to see that genius does not allow itself to be dragooned and that invention, like divine creation, has its mysterious

Great European Contemporaries of Edison



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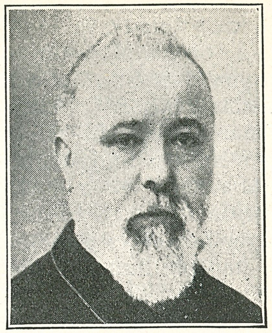

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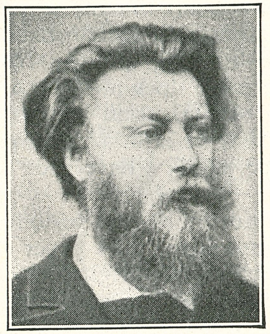

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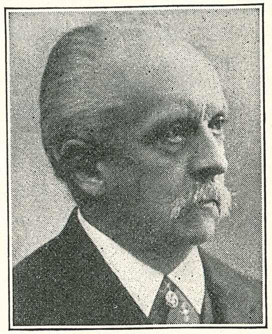


HELMHOLTZ

views which it is permitted to no one to penetrate and which defy all human calculation.'

M. Fontaine, author of a book on the electric light, editor of the *Revue Industrielle*, and president of the Syndicat of Electricite, when questioned regarding the *Herald* article, said: 'I have read everything published on the subject. My conviction is that by the employment of the carbonized horseshoe Mr. Edison has made an important advance in the matter of the electric light. I believe that the result has been obtained by a certain dexterity of manipulation of which Mr. Edison has preserved the secret; as, for instance, the judicious em-

ployment of the electric current during the process of carbonization.' Fontaine, I might add, had worked for some time with the Lodyguine lamp in the hope of making it successful. His book, written in 1878, criticized Edison, who was then working on his platinum lamp; it said 'that Mr. Edison nor any number of Edisons will for a long time to come displace carbon as a burner.' Here Fontaine was right; but he erred like many others in asserting that 'the subdivision of the electric light is impossible of attainment, and the disintegration of carbon when made incandescent rules it out of consideration for small burners.' The New York *Herald* article, of 1879, however, giving detailed explanations for the first time, induced him and many others to alter their opinions.

Another celebrated French savant, Jean Baptiste Dumas, who was at that period considered one of the greatest scientists of the day, expressed himself thus: 'I see no real impossibility in the thing' . . . 'I am led to conclude that Edison must employ considerable force and it is difficult for me to understand how he can long render incandescent a carbonized substance so little conductive as the drawing (in the *Herald* article) represents' . . . 'My scepticism does not go to the extent of denying the authenticity of the actual facts, for I know the skill of Mr. Edison and that he is in a position to arrive at different results from those which I have been able to obtain in my laboratory.'

Du Moncel was very hostile to Edison at that period. It was said that he was about to become editor of a paper that was connected with the Werdermann arc lamp. If such was the case, we can see that he had personal reasons for his opposition. The Werdermann lamp was one of a small type which attracted attention for a short time. Its peculiarity was that its negative carbon was shaped into a small plate and was fixed. The positive pole was a slender rod of carbon pressing against it lightly; that is, the contact was loose. The lamp was supposed to work on a semi-arc and incandescent principle. Werdermann connected his lamps in parallel in an attempt to solve the problem of subdivision. Of course the lamp did not achieve practical success; its light fluctuated and required trimming and constant care like all other arc lamps.

When De Fonvielle was asked about the onslaught made on Edison by Du Moncel in *Le Temps*, he expressed surprise that so respectable a journal should have printed it. An

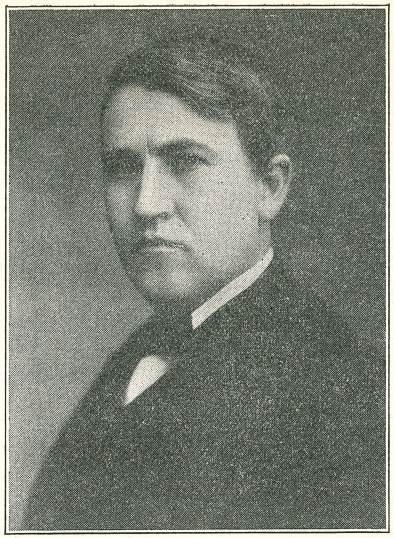
article in *La Lumiere Electrique* also written by Du Moncel said 'the public have forgotten the existence of such things as American *canards* (hoaxes). Edison is an ingenious and fertile inventor, but he is not well versed in the subtleties of electrical science, not acquainted with discoveries made before his time . . . Edison has paid no attention to maximum effects.' Du Moncel, like Preece, changed his opinion of Edison when he learned what Edison had really achieved and saw his exhibit at the great Paris Exposition of Electricity in 1881.

The German physicists who were on the whole conservative in their opinion, awaited further news. As a rule they were friendly toward Edison and were certain that so capable a man would surprise the world again as he had done in the past.

The Italian scientists hailed Edison's new system of artificial illumination enthusiastically and considered its advent of great importance in the history of the world and of progress. Foremost among them in enthusiasm was Professor Guiseppe Colombo, of the Royal Polytechnic in Milan. Proclaiming the dawn of a new era he declared that Edison was far more than an inventor, he was a discoverer. Professor Colombo was among the first to introduce the Edison system in Europe in a practical and commercial way and was the very first to raise the necessary capital for an Edison commercial central station on that continent, which station was erected at Milan, Italy.

Notwithstanding that persons of biased judgment existed in Europe as in America, Europe on the whole hailed Edison as the coming man with a magic lamp for all. Europe not only contributed loyal support to Edison's achievements, but led in the successful introduction to the world of the Edison system. There was a time when more Edison incandescent lamps were in operation in Europe than in America.

It may be well to explain that Professor Proctor mentioned on page 537 must not be confused with the Proctor mentioned on pages 478 and 479, whose memory erred in favor of Swan.



EDISON in 1904.

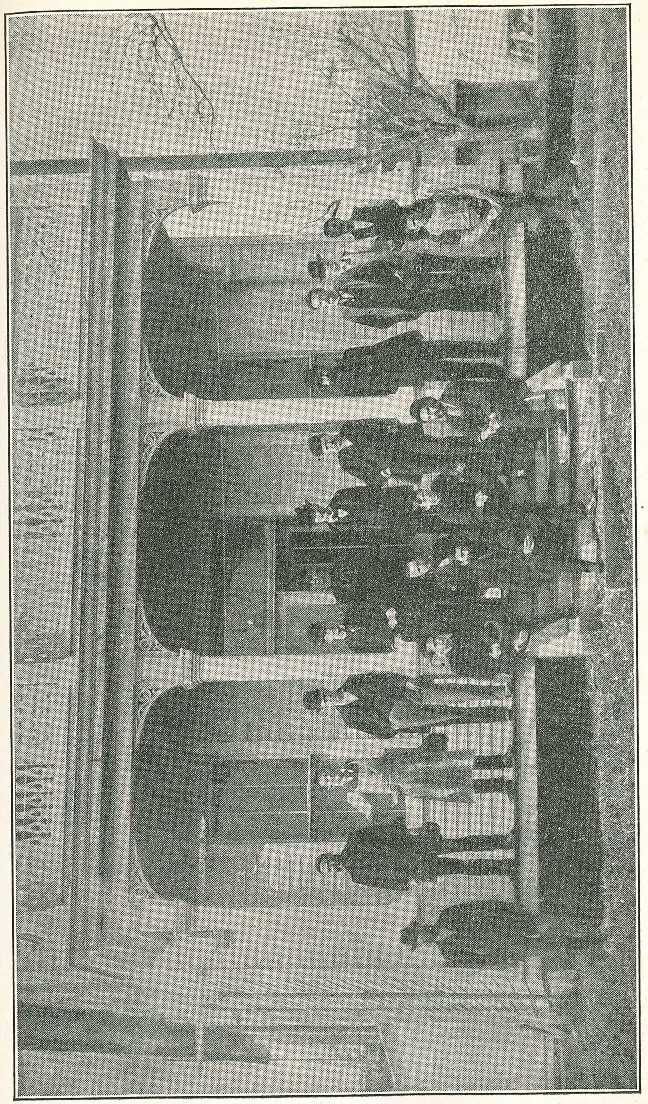
LXII. More Names for the Roster

IN ALL my articles I have depicted Edison as I knew him and saw him at work in Menlo Park, Edison as he was at the zenith of achievement and fame.

I was with him when only a few of us worked on that upper floor of the laboratory; when he toiled until patience and sagacity had overcome all obstacles and the world salaamed before him: Edison, a great young man, and yet human and affable in the extreme. I say that all these congenial traits of his virile character were real and genuine, and they attracted us to him more and more.

It would take the pen of a Dickens or a Victor Hugo to describe those days and nights at the laboratory prior to October, 1879.

The period preceding that date opened the first chapter in the history of electric lighting by incandescence. It was the creative period, marking the beginning of that progress which was to raise the standard of living for all classes of



Edison and group of assistants in 1880. Left to right (standing)—J. Ayers, James Hipple, ..., George Dean, William J. Hammer, John Lawson, Samuel Mott, Thomas A. Edison, William Holzer, Dr. Otto Moses, ..., ..., ... (Seated) C. Van Cleve, William Mills, William Carman, George Hill and M. Isaacs.

men. In the tenets that Edison expounded during the creative period of 1879, he uncovered facts that enabled other brilliant and energetic men to attack problems of similar nature.

The Edisonian creative period of 1879 employed but few men, as I have said. With the advent of December and the commencement of development and public introduction, we observe a notable expansion in the employment of men of varying mental capacities. From the combined group that served in these first periods, only a relatively small number possessed the ability to take advantage of the great opportunities that Edison gave each and every one.

No matter where they worked—in laboratory, machine shop, office—the boys who had not only the ambition but also the capability, Edison always rewarded. He picked them out and intrusted them with independent work. Those without self-reliance went with the tide and received their usual pay envelope. In past chapters and in those that will appear in the future, the reader will recognize the live-wire Edisonians. These Edison segregated from the others. They executed their work in various parts of the world to the chief's satisfaction. In the early history of the art they were standard bearers, leading the way. They were the earliest pioneers of incandescent lighting. They all succeeded in life—some amid more or less strange vicissitudes over which they had no control.

If certain of those who 'floated with the tide' have grumbled because Edison did not do this or that for them, I can only say they themselves were to blame. Had they reached for the possibilities that lay in those early years, they would never have had cause to regret. The servant is worthy of his hire; but no man can expect to receive more than his worth.

Some of Kruesi's men at Menlo rose to honored positions in the art, as did some in the laboratory and office. Others left us and succeeded in business for themselves.

When a scientific expert from *Scribner's Monthly* was sent to learn for himself of the correctness of sensational statements Upton had placed in an article, a lad named Albert Herrick accompanied him. This young man attracted Edison's fancy, as my narrative relates elsewhere, and was invited on the spot to join the staff. He was added to the pump gang and did odd jobs besides.

Many years after he had left us to enter a course of study in some school, I met him again; it was on my return from Europe. He told me that he had taken up switchboard

construction and had written a book on that subject. This is one of the simpler examples of opportunity grasped.

I shall now tell you about some of the men who joined our ranks early in 1880. There was William H. Moore, who had been selling the Weston plating dynamo in 1878 in England. That was the dynamo which John Campbell(1) described as 'those machines with water-cooled field magnets.' Subsequently he was sent to China and Japan in quest of the best kind of bamboo for the bamboo filament lamp. Edison supplied him with a good microscope and other utensils so that he could make satisfactory tests of the samples he acquired in China and Japan. His travels in the East form a romance, and the results of his work and findings established the Edison bamboo lamp as a standard for more than ten years. Later Edison sent others to South America and elsewhere without any appreciable results, for Moore's search in Japan had settled the matter of the best structural fiber for the lamp. He was always known to us as 'Japanese Moore.'

Another addition was Patrick Segedore, who followed Moore in search of vegetable fibers in Cuba and while there was stricken with yellow fever and passed away.

Others were C. Van Cleve, R. MacGregor, William Mills, David K. Hickman, George Crosby and George Hickman.

There was also Dr. Herman Claudius, who was once associated with the Austrian Imperial Telegraph Department. He was an eminent electrician and engineer of the old school, one who worked with minute fractions—a variable millimeter gouger. He was placed on the job of constructing a miniature network of conductors, all in proportion, to show Mr. Edison what he would have to install in New York City in connection with the Pearl Street Central Station. It was a gigantic task, requiring nerve and a super abundance of patience and knowledge. Only a German of that old school who had the Poggendorf or Kirchoff laws of conductor mesh work at his finger tips could have been fitted for the solving of those mathematical equations and propositions. From the data Edison received from men sent to New York City to determine the quantity of light and power that would probably be used, Claudius made small spools representing in proportion the load resistance. These spools were connected across the miniature distributing mains in their

(1) John Campbell was engaged by Edison at the Goerck Street, N. Y. C., Edison Machine Works in 1881.

respective streets on the board.(2) Then miniature feeders were fixed at various points, all running to the station; a battery supplied the current at the station. In this manner studies were made of the distribution of potential all over the network. Seated on a high stool, Edison would work with Claudius for hours making measurements. Again, we see the masterly proficiency of the man in his attack on this pioneer problem of the first central station in the world. It is astonishing how those prolific conceptions of his always found the ways and means of solving propositions. No scientist in those days could have evoked such brilliant conceptive visions in analyzing the stupendous difficulties of that situation. There existed no man who could solve them with such Napoleonic strategy. When I reflect on those days, I am more than perplexed how to express his greatness and his supermentality, for they pass the confines of human understanding. Yet this great man with all his sublime achievements for the race was often attacked in most dastardly fashion by his inferior brethren. We shall speak again of Claudius.

To Kruesi's staff were added Julius L. Hornig, a mechanical engineer, Hugo Andersson, Anton R. Westerdahl, John Kelly, Charles Flammer, George Dean and John H. Vail. To the office staff were added Charles T. Hughes, Ernest J. Berggren, Charles P. Mott and Edward C. Rowland.

ERNEST J. BERGGREN

'As a boy, Berggren found a job in the Menlo Park office.'

Hughes, a commercial man, was engaged as a buyer. He supplied us with material needed for laboratory or shop, journeying constantly between New York and Menlo Park. A fine and agreeable man, he was esteemed by all. He brought us the first specimens of bamboo from New York after he had found them in the Japanese stores. In those days when Edison worked with extra speed, if something was wanted he had to have it

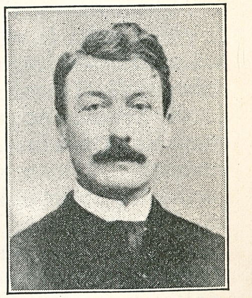
(2) Later on in 1881, Hermann Lemp wound the resistance coils that Claudius needed in his work.

at once and it had to be of the best quality. Later, when Edison moved to New York City, Hughes remained in his place to receive guests who came to see the electric railway. Hughes also took an active part in the commercial introduction of the Edison system and became a leading official of the General Electric Company when the latter was founded.

As a boy Ernest J. Berggren found a job in the Menlo Park office, later becoming an assistant to Carman, Edison's bookkeeper. Berggren worked for Edison many years as an expert accountant, and also served with the General Electric Company in the same capacity. He was always a hard and conscientious worker.

As regards his first night at the Edison office of the Menlo Park laboratory he writes: 'I shall never forget it. There I was, a young boy in the very presence of, and working with, the much-talked-about "Wizard of Menlo Park." I could hardly believe it—I was awed—struck! My first job was to assist in sorting and classifying these things (papers pertaining to a telephone interference). Mr. Wilber, of the firm of Dyer & Wilber, Mr. Edison's patent attorneys, was at Menlo Park that day for the purpose of collecting exhibits, drawings and notes and all the data on the subject to take with him the next morning to Washington for the hearing set for that day. Consequently my first job was to assist in sorting and classifying these things, and I spent my first afternoon and most of my first night on the upper floor of the office building in company with Messrs. Edison, Wilber, Batchelor, Kruesi and Carman.'

Charles T. Mott did office work, and E. C. Rowland was a patent draftsman. John H. Vail was engaged by Kruesi in the machine shop in June, 1880. His first job was to refit a small commutator. He wrote to me once saying, 'Not knowing anything about the importance of insulation, when I got it finished, it was N. G. (no good). Kruesi discharged me, but took my name and



S. D. MOTT

Mott entered Edison's employ in summer of 1879 as a patent draftsman.

J. H. VAIL

Mechanic and dynamo tender at Edison's machine shop who later did eminent service in the introduction of the Edison system in America.

address. He sent for me the following October. I began again, this time in the dynamo room(3), about October 10, 1880.'

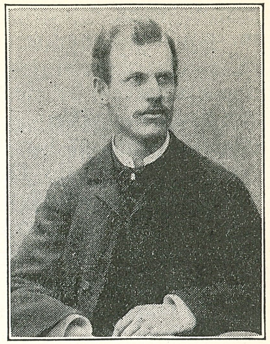
As dynamo tender in the second demonstration, Vail did good work. The generators sparked badly with the ever-changing load to which they were subjected when the exhibition was on. Hence to attend to eleven dynamos was no easy job, for the brushes had to be continually shifted to the neutral point.

When Edison and the 'boys' left Menlo Park in 1881, Vail followed. He was given charge of the lighting plant installed at the Edison headquarters at 65 Fifth Avenue, New York City. It is enough to say that Vail later took an active part in the introduction of the Edison electric light system in America. He, too, like Charles L. Clarke, Martin Force, Francis Jehl, Wilson S. Howell, William J. Hammer, Edward G. Acheson and William S. Andrews, was intrusted by Edison with the high honor of going into the world to float the Edison standard. These 'boys' possessed the self-reliance and energy to take up independent work, and all did their part for the Edisonian cause in pioneer days.

While mentioning workers of the period, I shall add a few not quite in chronological order. Another 'bright boy' whom Edison engaged later on (September 12, 1880) was Edward G. Acheson. He was descended from a distinguished family whose ancestors were traced in Burke's Peerage. Like many such families, his, too, in the course of time, suffered reverses. Acheson hailed from the 'round corner' at the intersection of Main and Maiden streets in the town of Washington, Pennsylvania. His boyhood days were spent at Monticello and he was educated in the district school, later receiving a year in a boarding school at North Sewickley, Pennsylvania.

As a youth he possessed an avidity for knowledge and evinced a special liking for geometry and surveying. When

(3) The dynamo room referred to relates to the second demonstration that Edison gave during 1880-1881.



EDWARD G. ACHESON

After assisting Edison at Menlo Park in 1880, Acheson became a leading industrialist. Invented carborundum, aquadag, oildag.

the 'crash' came in 1873, he was forced to hunt for a job. He became a timekeeper, joined a civil engineering corps, was a sales agent and had an office that was also his bedroom. At length he became a tank gauger in the oil regions and then an assistant to the chief engineer of a civil engineering corps.

As this last job bore no special results, he came East to try again. Edison placed him under Kruesi, who assigned him to assist Hornig. A short time afterwards, he was placed with Mott in the drafting room and from there joined us in the research laboratory. Edison set him to experimenting with graphite for the purpose of pressing out filaments; for he wanted to try every available material as a filament, and to cheapen the process if it was possible. Bamboo was all right, but if he could make filaments from graphite by pressing them out with a hydraulic press, this would be a stride forward.

So Edison ordered a press and told Acheson when he succeeded in pressing out a filament that could be mounted in a lamp, he would give him a $100 prize. Acheson got the prize. He was always lingering about the chemical room and took a great interest in electrochemistry, working on ideas that had reached him before he came to Menlo Park. One was to add an element or solution to carbon so that by passing electricity through it, he could obtain electrolysis. He thought this would produce carbon in crystallized form, either on one of the electrodes or on the sides and bottom of the cell. As he lacked the means for experimentation, he asked Edison's permission to use laboratory equipment to dissolve iodine in paraffin and, employing carbon, try to break it up with a current. Nothing came of it.

At this time Edison was also engaged in depositing carbon on filaments by means of hydrocarbons through heating the filaments in a closed vessel. Meanwhile Acheson continued the manufacture of graphite filaments with the hydraulic press, obtaining a wonderful light. But they had no life and

disintegrated rapidly. In November, 1880, these experiments were discontinued and Acheson asked Edison what he should take up. Edison prompted him to continue his efforts to deposit carbon by electrolysis, and gave some instructions on the course to take. Acheson made many trials with different chemicals and at last found one which gave a deposit in the bottom of the cell. On examining the deposit, Acheson found some crystals which he showed to Dr. Edward L. Nichols, who said that they might be carbon in a diamond state. When Acheson reported to Edison, the latter told him he was not after diamonds but only black conducting carbon; and so the matter ended. Acheson changed to other duties.

He was of a restless nature, always pondering on electrochemical problems; his only ambition seemed to be to possess the means that would enable him to go on with his experimenting. He was quiet and serious, and yet a good companion. When Edison moved to New York in February, 1881, Acheson and I remained in Menlo Park. I often enjoyed strolls with him evenings. During the conversation he avoided commonplace talk and spoke of chemical questions that seemed to fill his mind. I do not hesitate to add that he took advantage of every occasion to make experiments on his own account.

There seemed an urge in him so different from the spirit in other 'boys' that a sharp observer would have said, 'Here is one who is bound to succeed in life.' He often praised Edison's method of experimenting, because only thus, he believed, could results be obtained. Persistence and discernment were necessary to success in any endeavor. That Acheson possessed the firm courage of his convictions I know well from occurrences in the laboratory, as well as from others while he was in Europe; I know, too, that he possessed the greatest integrity. At the same time he did not hesitate to express his honest opinions.

After he had finished the work on the graphite filaments, Edison intrusted him with other important tasks in chemical application. He tackled the problem of making graphite moulds for carbonizing filaments, so as to do away with the costly nickel ones; and of making a plaster of Paris composition for the lamp socket. When he was designated to go over to Paris in 1881 and assist Batchelor in getting the Paris exhibition in order, he took a course at the Menlo Park lamp works and then assembled the instruments that were to be

displayed. Edison had him prepare the first display cases wherein was shown the process of manufacturing bamboo filaments, from the raw stick to the finished carbonized filament.

After the Paris Exhibition he was sent to Milan to make a trial demonstration of Edison's system at the La Scala and then at the Cafe Biffi in the Galleria Vittoria Emanuele in the same city. He afterwards directed installations in other parts of Italy, Belgium and Holland. On account of some difference of opinion with one of the commercial directors of the French Edison Company in Paris during January, 1883, Acheson left the company and settled down to experimental work of his own.

He was soon out of money and failing in health. He went to London in December, 1883—'dead broke.' Samuel Insull, who was also in London on Edison business, cabled Edison about Acheson. Edison provided the financial means for Acheson to return to America. When he arrived home again Edison put him on a job back at the old almost deserted laboratory in Menlo Park, where, however, he did not stay long. He vegetated around from one company to another, always trying experiments, and at last got out a patent on an anti-induction telephone wire that brought him seven thousand dollars cash, shares, and a position as an electrician.

At the end of three years he again found backers for his pet hobbies of converting heat direct into electricity and of research in carbon, graphite and synthetic rubber, which proved unsuccessful. In 1890 he moved to Monongahela City and organized an electric light company. Although that venture did not pay, it afforded Acheson the means of experimenting with heavy currents to his heart's content. Perhaps he used more current in those experiments during the night than the little station sold, but his results were crowned with far-reaching success.

He now reverted to experiments made for Edison at Menlo Park in 1880 and worked up carbon in all forms with the aid of a crude electric furnace. To make this story short, he found that he had succeeded in making an abrasive that was nearly as hard as a diamond; in fact, he had made silicon carbide, which he called 'Carborundum.' This was in 1891. His name and fortune were assured. When we look back over the ten years from the day he first started at the laboratory, and follow him through trials and vicissitudes of the bitterest

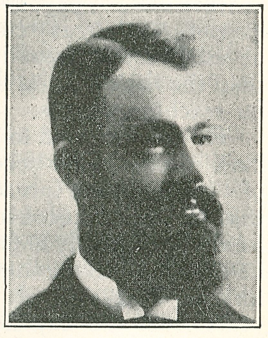
kind, we must confess that his indomitable will, when odds seemed against him, brought at last well deserved triumph —the results of persistence, ability and a healthy lookout for new ideas.

Dr. Edward G. Acheson has since produced many useful inventions, among which colloidal graphite is one of the most important. This material, when dispersed in oil, is best known by the trade mark 'oildag.' He was honored and counted among the great industrialists of our period; his life has been an inspiration for coming generations.

I have purposely gone into a lengthy description of the man and his work, for it is a part of Edisonian history. He made a great success in life, and thoroughly studied and understood the precepts of our master. He managed to 'out-dazzle' us all with the resplendency of his achievements, and is the sole instance of a former Menlo Park 'boy' whose later work was crowned with eminent success, reflecting more than special credit on the great man who guided him.

If we review the life work of some of the other boys who were given the same chance, we wonder why and how it was that he was so brilliant. Perhaps Longfellow's theory —'Most people would succeed in small things if they were not troubled with great ambitions'—applies. Honestly speaking, I suppose few if any had the energy, ability, endurance and vision required, although it is hard to admit. Results are what count, and where they are lacking, no amount of explaining can alter the judgment. Most of us were, to put it plainly, satisfied in serving Edison, and had no greater ambition than loyalty.

About the same time (autumn, 1880) came Dr. Edward Nichols, Upton's friend, who too had finished his studies at the University of Berlin in Germany. During his brief stay in the laboratory he worked, at Edison's suggestion, on a possible form of a chemical meter in which copper or some other metal was deposited on plates suspended from the arms of a balance, the current being reversed automatically and periodically by the tipping of the balance arm. Later



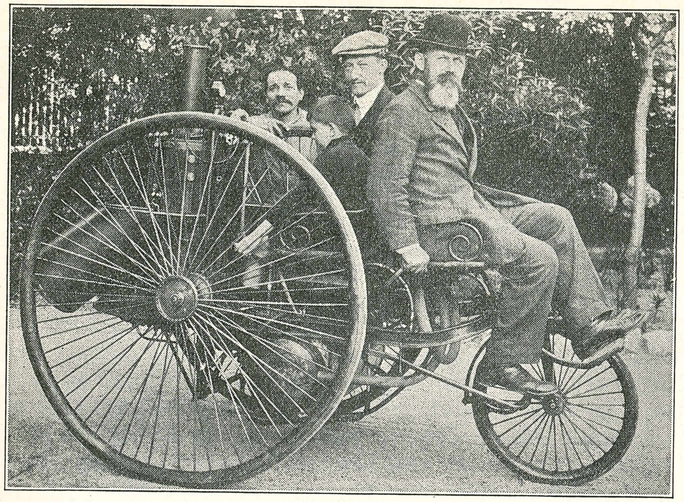
DR. EDW. L. NICHOLS

he was transferred to the lamp factory. While there he spent a month studying the troublesome eccentricities of the Sprengel mercury pump. His final work at the factory was the designing and constructing of a photometer and two electrodynamometers used in sorting lamps for voltage and current. Dr. Nichols resigned in the summer of 1881 and was succeeded by John W. Howell. Nichols went from Menlo Park to a college in Kentucky, where as a professor he taught chemistry and physics. He later became one of the pillars of Cornell University at Ithaca, New York.

One of the last brilliant young men to enter as a volunteer was Rene Thury, of Geneva, Switzerland. He came to us during the autumn of 1880 accompanying a man who was seeking European concessions from Edison. Thury was introduced to Edison in the library, and when the latter heard his name he said, 'I know that name. Are you the son of Professor M. A. Thury who has written scientific books?' Among those books was one well known in the United States which related to the origin of life. 'Yes, sir, my father wrote them,' answered Thury. Edison smiled, and welcomed him warmly, and then with kind words invited him to become one of his volunteer staff. Thury was a good mechanic and at the same time an electrician who understood all there was to know at that time about the mysterious force. In 1878-79 he and his friend Nussberger had constructed a steam automobile that ran around Geneva. It is now preserved at the Automobile Club in that city.

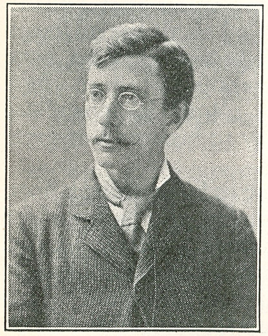
Writing of those Menlo Park days Thury says: 'The recollection of the time I was with Edison is still vividly impressed upon my memory, and it is not without regret that I think back to those happy days at Menlo Park. I recall the intimacy of Edison with his personnel. The liberties that he gave each of his men to accomplish the tasks assigned to them and the harmony that reigned among all so impressed me that I had the passionate desire some day to become a member of this family.'

Thury's ardent desire was to continue to be an Edison man, but fate decided otherwise. The Swiss syndicate that wanted to establish a Swiss parent Edison company at Geneva failed to realize the project because of the stupidity of its experts. These experts informed their financial men that the Edison lamp and system had no chance of success in the future. However, Thury was not lost when he returned home in 1881.



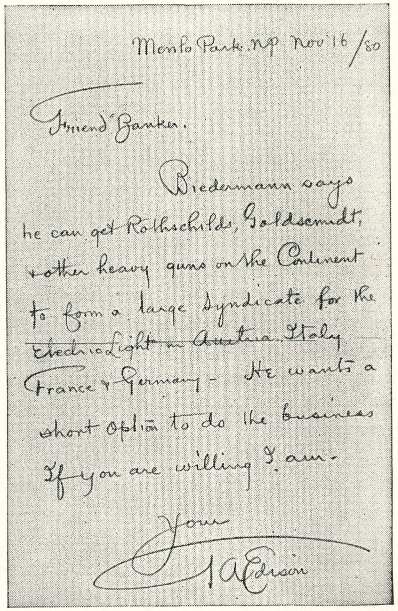
Rene Thury on his steam tricycle in 1880. With four passengers he attained 50 k. m. an hour.

He became one of the leading electrical engineers on the continent and his name is familiar to all old-timers who know anything about the history of electric lighting. He designed high-tension, direct-current, multiple dynamos together with a series system of energy distribution. In some of the central stations built by him, direct-current generators were in series. In the installation of Moutiers-Lyon he obtained 100,000 volts and 150 amperes direct-current. At Saint-Maurice Lausanne he delivered 5,000 horsepower at 22,000 volts direct-current with a single wire, using the earth as a return. He built several stations with high tension direct-current, all of which created professional excitement at the time. He was also a pioneer in electric traction. M. Thury passed away in April, 1938.



CHARLES L. CLARKE

Edison Proposes Concession to European Promoter



Menlo Park NJ Nov 16/80

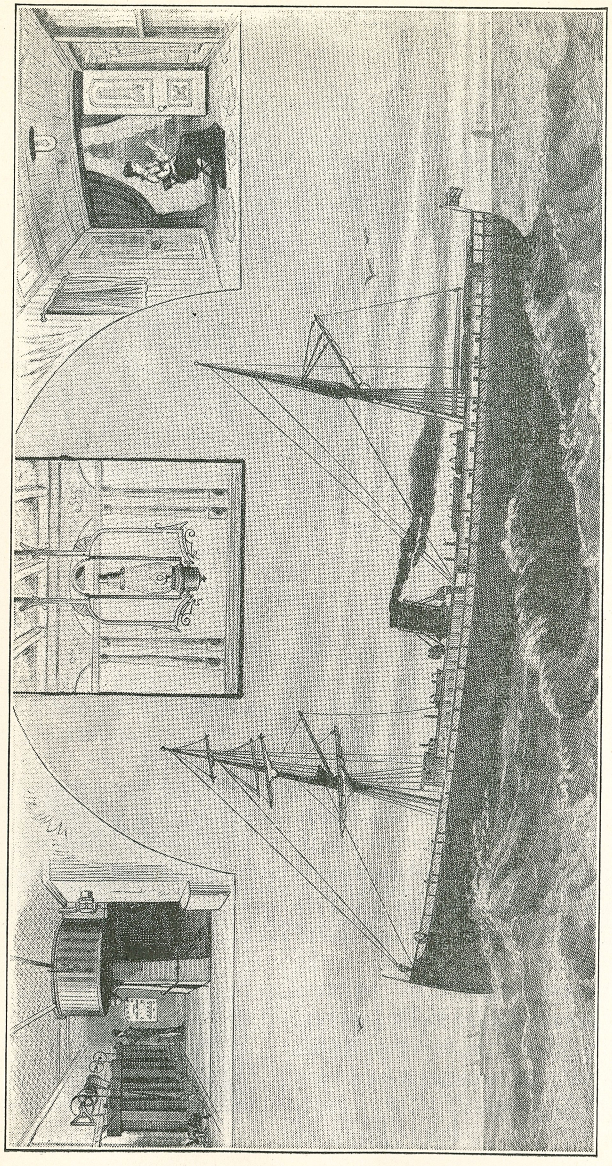
Friend Banker.

Biedermann says he can get Rothschilds, Goldscmidt, & other heavy guns on the Continent to form a large Syndicate for the ~~Electric Light in Austria. Italy~~ France & Germany - He wants a short option to do the business If you are willing I am.

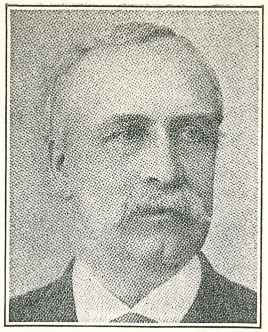
Yours

T A Edison

James H. Banker was one of the original incorporators of the Edison Electric Light Company. Biedermann was said to be related to Goldschmidts of Berlin, Germany, who at that time were one of the prominent bankers of Germany. It was Biedermann that brought Thury to America to study the Edison system. (This letter from historical collection in The Edison Institute Museum.)



The steamship *Columbia* built in 1880 for Henry Villard, president of the Oregon Railroad and Navigation Company. Upper left, generators installed by Edison on the *Columbia*; center, oil lamps were kept in reserve; upper right, luxury of electric light aboard ship in 1880.



HENRY VILLARD

LXIII. Lighting the S. S. *Columbia*

THE installation of Edison's system of electric incandescent lighting on the S. S. *Columbia* was the first commercial application of the art in history. The work of constructing the ship's plant was commenced in April, 1880, at a time when the world was still discussing the wonders of Edison's achievements at Menlo Park. Crowds were still flocking to his laboratory in that lonely hamlet in New Jersey to get a glimpse of the little wonder lamp that was to establish the coming era in a new art of illumination.

It was also while the Edison electric light plant was in the process of being installed on the *Columbia* that discouraged glow-lamp experimenters in England, America and elsewhere began raking up the debris of their abandoned attempts and emerging from the coma into which failure and discouragement had thrown them. These carbon rod (or pencil) men who had only succeeded in generating soot and heat with their low resistance, short-lived *lamps* as they called them, were suddenly revived into scientific activity with the first hypodermic infusion of Edison's success. Yet the first com-

mercial incandescent light plant was in actual operation on the *Columbia* as she plowed through the waters of the Atlantic and the Pacific oceans long before infringers, adapters or experimenters had succeeded in making a durable and practical incandescent lamp of high resistance and small radiating surface after Edison's pattern.

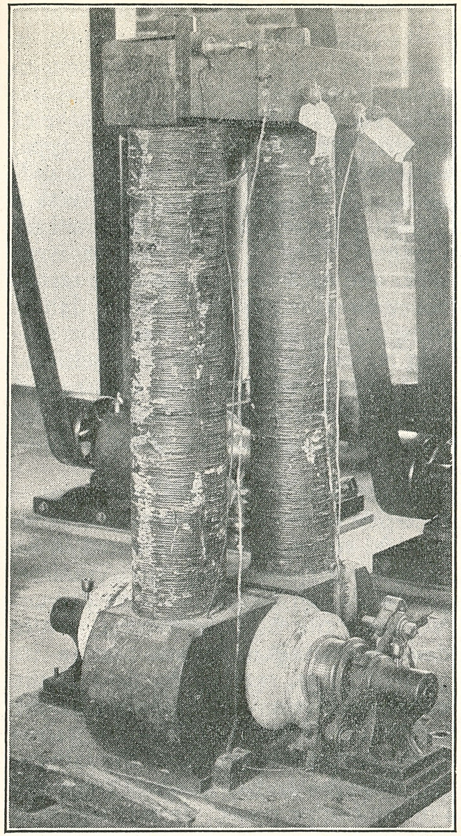
It took a long time in those days to duplicate the Edison lamp, which in principle was not yet fully understood by those who had hitherto been working on the carbon rod principle. The reason for Edison's precedence in the field was that as a full-fledged electrician and profound thinker he knew all about the requirements of an electric central station supply before such a thing existed or was even visioned by another. Thus electric incandescent lighting history began in a practical way at Menlo Park, New Jersey, in 1879, and in commercial exploitation in April, 1880, when the S. S. *Columbia* was outfitted with the Edison system.

I have reiterated these impregnable facts in order to paint in the void, electrically speaking, in the midst of which the *Columbia* scintillated when Edison lighted her with his system. And so comprehensive was the knowledge that Edison thus climactically gave at that time, that today, after more than half a century, it is still fundamentally retained in practice. The history of this interesting plant is as follows:

The S. S. *Columbia* was built by John Roach at Chester, Pennsylvania, for the Oregon Railway and Navigation Company, whose president was Henry Villard. She was 334 feet in length with a beam of 38½ feet, a depth of 23 feet, and a capacity of 3,200 tons. She was expected to make an average speed of about 14 knots an hour. Her fittings included all the improvements of the day and made her one of the finest steamships afloat.

Villard was a hustler and a man of vision who when he saw the Edison light at Menlo Park in December of 1879 made up his mind immediately to have it installed on the *Columbia*, which was then in the process of building. When old John Roach, the master shipbuilder of this country, was informed that the *Columbia* was to be fitted out with the new fangled light invented by the fellow over at Menlo Park, he shook his head disapprovingly. 'Let them try it out on land first but not on a ship,' said he.

It was also murmured that the marine underwriters would object. All this, however, did not deter Henry Villard, who



Original Edison dynamo used on S.S. *Columbia* and now in restored Menlo Park machine shop at Dearborn.

had implicit faith in Edison and his light. Villard, it may be said, later became prominent in Edison affairs and at one time was president of the Edison General Electric Company at Schenectady.

And so in January, 1880, Edison received as his first commercial order a contract for equipping a steamship with his new lighting plant—a two-wire system with feeders and distributing mains.

Kruesi was immediately put on a rush job to make four Edison generators while Sigmund Bergmann in his Wooster Street factory in New York was making all the necessary electric accessories and fixtures.

J. C. Henderson, of the navigation company, came often to Menlo Park in the early part of 1880 for consultation with Edison and Upton on the subject.

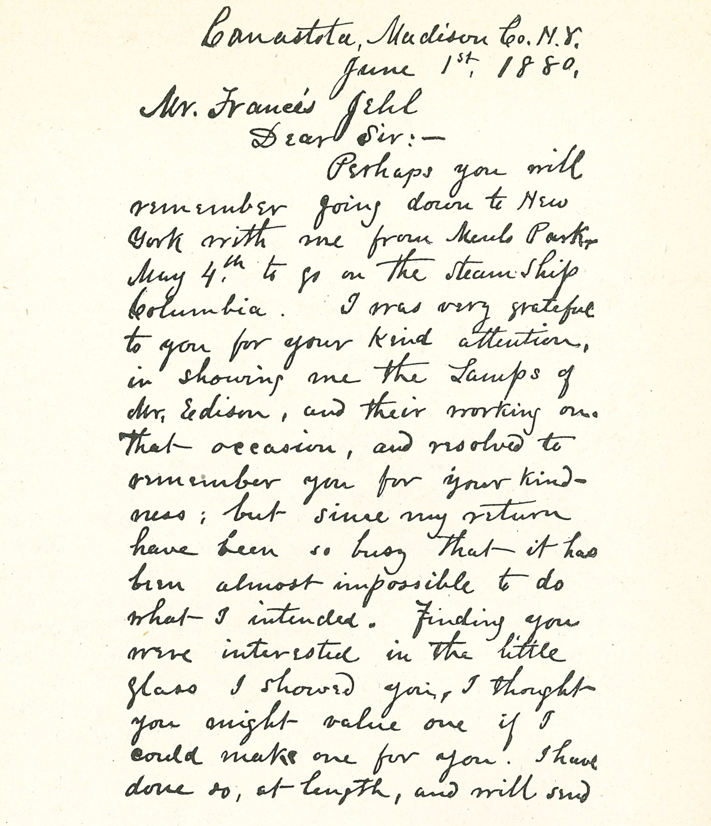
The *Columbia* was launched on February 24, 1880. She left Chester under the command of Captain F. Bolles, with Henderson as chief engineer and company's adviser. On arriving in New York, she was docked at the foot of Wall Street where she received her cargo and was equipped with the Edison light.

The dynamos that were installed on the *Columbia* were of the same type as those used at the first central station in Menlo Park during Edison's demonstration of his system in 1879-80, with the exception of the following improvements:

In the place of a vertical standard attached to the base of the machine for commutator brushes of the sliding type, Edison introduced a turning rocker, which has been the standard brush holder ever since. A second improvement was a plug switchboard with binding screws that was mounted on the front part of the magnet yoke. The dynamos were designated as the 'A' type, and each had an armature resistance of 0.14 ohms. Each generator supplied 60 'A' lamps of 16 candle power having carbonized paper horseshoe filaments. Today they would be termed six-kilowatt machines. It might be mentioned that these generators were constructed with wooden bases; for it was several months before Edison made the iron bases that were to be used in the second demonstration of his system in 1880-81.

The four Edison generators were arranged in a line—tandem fashion—along one side of a wall in the engine room of the *Columbia*. Two vertical steam engines, mounted in an adjacent room, supplied the power through belts to a countershaft from whose pulleys the Edison generators were driven. Three of the dynamos supplied the lighting current, while the fourth, which had a regulating resistance box in its circuit and was driven at half speed, excited the field of the other three. This system of regulation was the same as the one used at Menlo Park except that instead of using a galvanometer to keep tally on the tension as we did at the laboratory, the attendant on the *Columbia* had to judge it from the brightness of the lamps in the engine room. In fact this was the method used in all later plants until pioneer apparatus was devised for the purpose of regulating.

Before the industry of lighting by incandescence, which had just been started on a practical scale by Edison, could expand, it is evident that many accessories had to be developed, the most urgent being insulated wire. The only insulations on the market were the crude covering of paraffined cotton used on call bell wire and the simple cotton covering used in arc light systems. In a word the art of making insulated wire for electrical purposes was in its earliest infancy and some time elapsed after Edison's achievements in electric lighting before the insulated wire trade became roused to


Canastota, Madison Co. N.Y.
June 1st 1880.
Mr. Francis Jehl
Dear Sir:—
Perhaps you will remember going down to New York with me from Menlo Park, May 4th to go on the Steam Ship Columbia. I was very grateful to you for your kind attention, in showing me the Lamps of Mr. Edison, and their working on that occasion, and resolved to remember you for your kindness; but since my return have been so busy that it has been almost impossible to do what I intended. Finding you were interested in the little glass I showed you, I thought you might value one if I could make one for you. I have done so, at length, and will send

First page of letter written to Francis Jehl by a visitor to whom he showed the electric lights on the *Columbia* before it left New York.

improve, develop and adapt itself to the new demand. Electricity would soon require vast quantities of wire that must be suited to different purposes.

Thus the wiring on the S. S. *Columbia* was of a crude sort with its simple cotton covering which would not today be passed by the underwriters. It was treated with hot paraffin to make it 'moisture proof' and after being mounted was usually painted, one color for the positive pole and another for the negative. When a line led over metal, a soft rubber

tubing was slid over it. The conductors were held to woodwork by iron staples such as were used in call bell or annunciator lines. The leads of each dynamo connected with a common switchboard, where they terminated in a two-wire bus with seven feeders running to various sections of the ship. Each feeder supplied an independent distribution circuit that distributed current to a certain part of the ship.

It is hardly necessary to state that each generator feeder had a plug switch and was fused so that one or the other could be thrown on or off as desired. (The fuses consisted simply of a lead wire placed in a glass tube, its extremities connected with the line wire by means of wood screws and metal washers on a wooden block.) All branch lines were likewise fused and provided with switches, which were under the control of the steward.

Thus if a person in a stateroom desired his light on or off, the steward had to be called to unlock a box outside the stateroom and turn the switch. The lamp sockets used were the same as those that were in operation in Menlo Park. They were of wood having two metal strips inside, to which the leads of the line were connected; the lamp base was operated on the jack switch principle. The lamps, of course, had to be used in an upright position, though by a special contrivance some of the stateroom lamps were inverted. While the steamship was on its voyage, the engineer demounted some of the sockets and connected them directly with the supply wires in a swinging position. His idea was to prevent the frail carbon filaments from receiving direct mechanical shocks that might injure them.

Oil lamps were everywhere in reserve. Most of the fixtures that were of a combination type were so arranged that if the electric light should fail, oil lamps could immediately be substituted. For the 115 incandescent lamps installed in this pioneer plant the current from two generators would have been sufficient. Edison, however, in his desire to provide ample reserve added a third unit. Francis R. Upton supervised the electrical part of the installation and John C. Henderson, advising engineer to the navigation company, had charge of the mechanical part, such as the placing of the vertical steam engines, the dynamos and the shafting.

As Edison could not spare any of his men to do the wiring, he requested Bergmann to send the necessary number. The plant was finished by the end of April, 1880. I went with

Upton several times to make insulation tests, the last of which took place on May 4 after Henderson had conducted a forty-hour running test of the whole plant. That day is strong in my memory; for a clergyman from Canastota, New York, who was at the laboratory in the morning accompanied me and at Edison's request I showed him all that was being done on the *Columbia*. Crowds visited the ship during this first exhibition of the Edison electric light system outside Menlo Park.

I often smile when I recollect with what care Upton and Wilson S. Howell carried the lamps from the laboratory to the steamer. The delicate things were wrapped in cotton batting and placed in a basket, and how carefully the two men walked through the streets in New York to avoid collisions with passers-by.

The S. S. *Columbia* sailed from New York in the early part of May, 1880, with a cargo of thirteen locomotives, two hundred cars and other railroad supplies. As there was no Panama Canal in those days the good ship had to round Cape Horn. She arrived at Portland, Oregon, on July 26. The Edison electric light system had finished its first practical test satisfactorily in every respect.

About this time Edison was busy making and experimenting with bamboo filament lamps and resolved to send some West to replace the paper horseshoe ones on the *Columbia*. We packed them carefully in three flour barrels and sent them overland. Old-timers will perhaps remember the days when lamps were sent in barrels. I always received them in that way when I was in Europe working for Edison.

On February 24, 1882, Chief Engineer Henderson sent Edison a report from which the following is an excerpt. 'On the night of the second of May, 1880, we started up the dynamos, and from the time when the steam was first turned on until the present they have worked to our entire satisfaction under all circumstances . . . Since the arrival of the ship on the Pacific coast, we have received a full supply of new bamboo lamps. How well they have worked can be best seen from the following report of Chief Engineer Van Duzer: I have now 115 lamps in circuit, and have up to date run 415 hours and 45 minutes without one lamp giving out.'

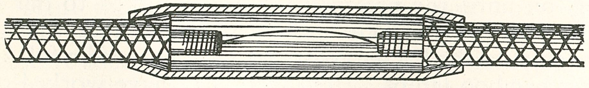
The pioneer plant continued in active service for fifteen years. In July, 1895, when the ship was overhauled, the old Edison plant gave place to a modern one. The *Columbia*

continued to ply between San Francisco and Portland until July 21, 1907, when she collided with another ship off Shelter Cove, California, and sank.

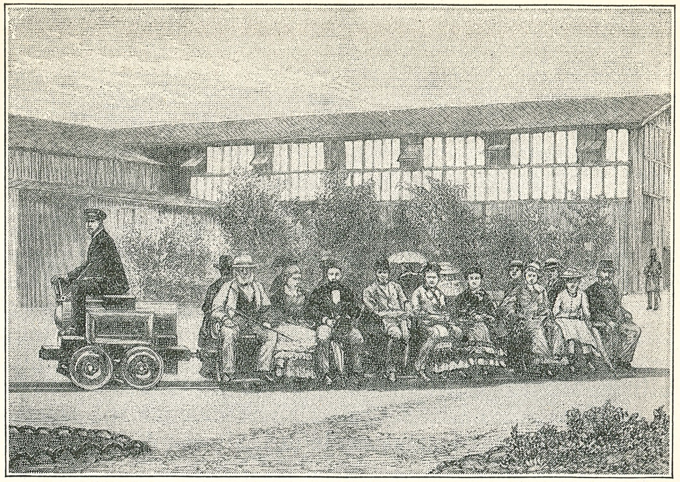
Two historical relics have remained from the world's first commercial electric incandescent light plant. When the old plant was demounted in 1895, the Oregon Railroad and Navigation Company returned two of the veteran Edison dynamos to the General Electric Company, successor of the Edison General Electric Company and the Edison Machine Works, the latter the outcome of the Menlo Park Edison Machine Shop where these dynamos were made. The General Electric Company presented one machine to the Smithsonian Institution and the other to Henry Ford who gave it a final resting place in its very birthplace, the Edison Menlo Park machine shop, now reconstructed in Dearborn. This historic dynamo, as well as the one at the Smithsonian Institution, is a witness of the days when Menlo Park, New Jersey, was the only place in the world where a practical incandescent lamp had been made.

Not even by the time the *Columbia* reached San Francisco had those carbon rod men been able to solve the puzzle of a high resistance carbon filament. I often muse on past days when I see the Edison generator in the machine shop in Dearborn. Yes, I say to the dynamo, 'Your master had to fight many battles when those infringers began their iniquitous rackets, and he won!'

Time has long since separated the real facts of Edison's great achievement from the accumulated mass of trickery and deceit that once attempted to rob him of his dues. Only pure Edison gold remains in the pan's washings, while the muck has gone where muck belongs.



One of the illustrations of Edison's patent (U. S. No. 227,226) for 'safety-conductor for electric lights.' In other words, the fuse adopted everywhere. Edison signed this patent March 10,1880.



Siemens' electric railway at Berlin, Germany, in 1879. First of its kind, it used a series-wound machine, the only make known at that time.

LXIV. The Electric Railway

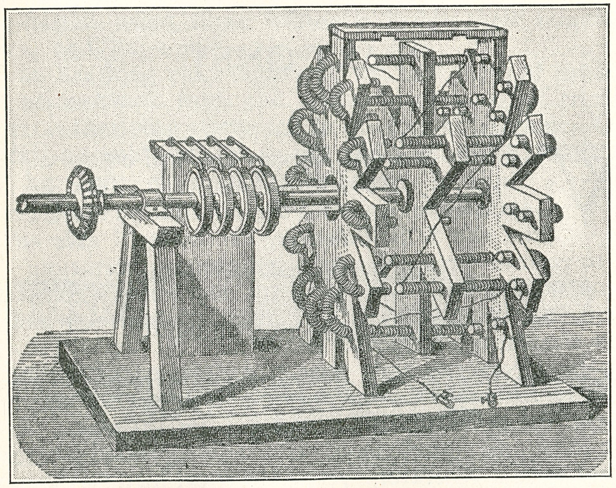
(PART ONE)

WHILE Edison was actively engaged on the different kinds of carbon filaments and filling his first commercial order for the installation of his system on the S. S. *Columbia*, he was still able to find time to go into the problem of electrical transportation. The idea of an electric railway was not a new one; for experimenters had worked on it ever since the wet cell and the simple electromagnet became known.

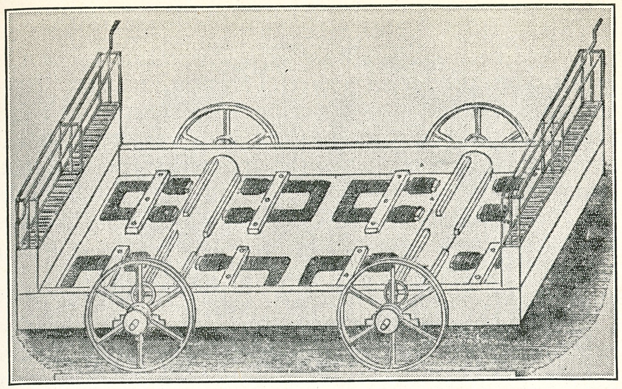
In fact from the start men had dreamed of employing electricity to supply power, but the time was not yet ripe—the practical generator and motor did not yet exist. As we know today, an electric motor is usually operated by current received from a generator—yet in electrical history the motor came first.

Barlow in 1826 proved that the energy from a wet battery could be transformed into mechanical power. The Barlow wheel seems to be the first instance on record of continuous electromotion. This apparatus consisted of a copper disc that revolved between the poles of a magnet when a current passed from its center to a point on its circumference. What a wealth of dormant possibilities were tied up in this experiment! For example, if Barlow had tried the reverse (that is, had rotated his disk by hand), he would have anticipated Faraday's discovery by five years. It is a curious fact that after Barlow's experiment it took five years to discover the essential principles of the dynamo. Development of Faraday's great discovery came in 1832 when Hippolyte Pixii of Paris built the first practical machine for the production of electricity by mechanical means. His commutator for the rectification of current was a great stride in itself and deserves special notice.

Let us recall a few of the early experimenters who were working those crude electric motors driven by wet cells. Among the multitude were the Abbe Salvatore Del Negro and Professor Jacobi in 1834; the latter, some will remember, propelled a boat on the Volga by means of a crude motor and



Jacobi's electromotor which propelled a boat on the Volga in 1834.



Davidson's electromagnetic locomotive. (Observe line of batteries at each end of car.)—1839.

a battery of many cells. In 1835 Thomas Davenport, a blacksmith of Brandon, Vermont, made a toy model of a circular electric railway which he exhibited in Boston and other cities; the rails were used as conductors, one for the positive and the other for the negative terminals. Davenport took out a patent on his ideas here as well as in England, seemingly the first ever issued for an electric motor. Robert Davidson, of Aberdeen, Scotland, followed in 1839 with an electric locomotive that was said to be the first ever tried on railroad tracks; he attained a speed of four miles an hour over the Edinburgh-Glasgow line. A patent was given to Henry Pincus in 1840 for the use of rails as conductors.

In 1842 came Elias with a motor that outwardly resembled Pacinotti's ring. Froment brought out another in 1845 and Hjorth patented one for which he obtained a medal at the London Exhibition in 1851. Among many other experimenters was Professor C. Page, who used the solenoid principle instead of the attraction and repulsion of simple magnets favored by most of the older designers. His electromagnetic engine in 1851 succeeded in attaining a speed of nineteen miles an hour on the line of the Washington & Baltimore Railroad.

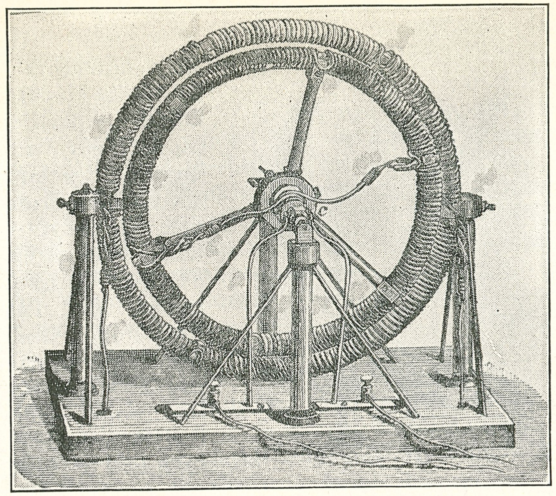
All these trials were unfruitful because there existed no cheap method for generating current and because the motor design was crude. The first practical advance in generator

or motor was made by that pioneer of electrotechnics, Dr. Werner Siemens, of Berlin, Germany. His shuttle wire armature, located between the poles of a horseshoe magnet, was in a position to produce a powerful current. Siemens' English patent of 1856 (No. 2107) describes his invention as follows: 'A cylindrical bar of iron is taken, and two broad and deep longitudinal grooves are cut in the opposite sides. A quantity of insulated or coated wire is wound in a longitudinal direction in these grooves . . .' It was in reality a one-coil drum armature, and the rectifying was done by a two-part commutator mounted on the shaft of the armature.

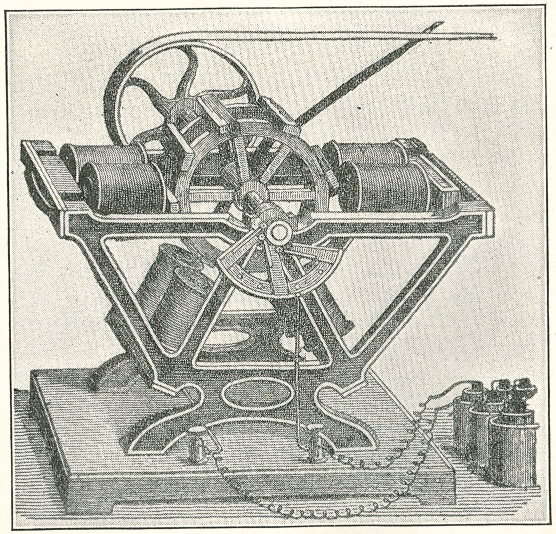
In 1860 Dr. Antonio Pacinotti, an Italian savant of Florence, made the great discovery of the commutator used today. He expounded the method of winding a motor or generator so that electric as well as magnetic forces operated effectively in a uniform and continuous manner. He also used a ring method of winding which appeared similar to that employed by Elias of Amsterdam in 1842, but from an electrical point of view, as we shall see, was altogether different. The discovery of the commutator, in providing an abundant supply of continuous direct current, was to give new impulse to the art—though it had to wait ten years before a practical man came to utilize it.

In the meantime, that is, in 1866-67, Dr. Werner Siemens, Sir Charles Wheatstone and S. Alfred Varley discovered that permanent magnets could be replaced by electromagnets in constructing an electric generator and that a part of the energy generated by the armature could be used for energizing the electromagnets. Thus, generators could now be constructed to supply direct current of an intermittent, varying strength. This was the birth of the series wound machine. Then came 1870, and the history of electrical generators reached a turning point. Zenobie Theophile Gramme, a Belgian by birth, while working as a pattern maker in Paris, invented the first dynamo electric machine to produce a continuous flow of current.

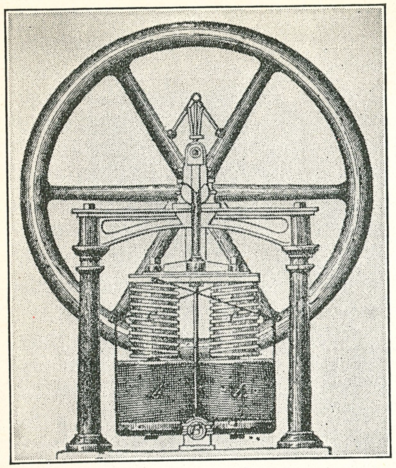
Though the commutator and the proper arrangement of a ring winding, as has been already noted, were discovered as early as 1860, none of the army of brilliant men working at that time on the same problem could vision the huge possibilities of Pacinotti's find. Ten long years passed, and then destiny picked out Gramme, who, using nothing more than common sense and good judgment, applied Pacinotti's



Elias' electric motor (1842).



Froment's electric motor (1845).



Hjorth's electric motor (1851).

discovery and almost in one coup determined the fundamentals of the dynamo-electric machine. Almost contemporaneously with the Gramme machine came the Siemens drum armature in 1872 for use with Pacinotti's commutator. I have mentioned that Elias, of Amsterdam, had a ring wound armature in 1842, and I might now add that in 1866 Henri Louis Felix Worms de Romilly took out a French patent for a drum armature. Their ring and drum strikingly resembled the ring of Gramme and the drum(1) of Siemens—with the same great difference, however, as was expressed by the English judge in the incandescent lamp case, when he said that 'the difference between Swan's carbon rod and Edison's carbon filament is the difference between failure and success.' Gramme and Siemens, reviving Pacinotti's discovery of 1860, had found the proper way of connecting the coils with the commutator.

Electrical history in 1870 therefore opens to a new chapter. Men were encouraged to strive for practical invention because useful tangible results seemed more possible than ever before.

At this time Edison was seeing for the first time the fulfillment of one of his early dreams. He had a shop and laboratory of his own in Newark and could now work as he wished. He was independent.

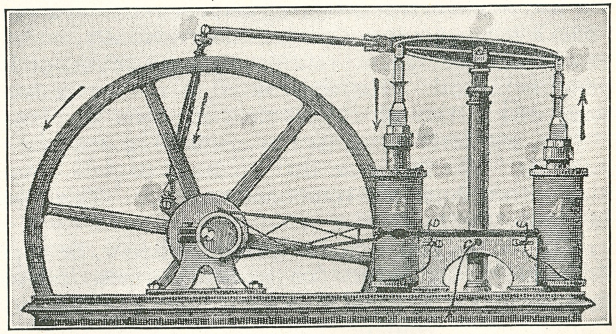
Experience has taught us that whenever a period of hope and confidence blooms for some new art, a crop of rogues ripens simultaneously to take advantage of the unsuspecting. In the same town of Newark such a mushroom appeared in the person of H. M. Paine. In 1871, papers everywhere were full of Paine's new electric motor! The *Journal of the Telegraph*, organ of the Western Union Telegraph Company,

(1) Made by Von Alteneck.

contained a wildly enthusiastic editorial about it. In the *Scientific American* Paine himself wrote: 'The forces developed by the action of a single Bunsen quart cell, if utilized and converted into power, would drive the largest ship afloat with a velocity only limited by the strength of the ship's frame.'

General Lefferts, whom we have already mentioned, was extremely interested in the new motor and decided to go to Newark to see it. Thinking it would be well to have Edison with him, he made arrangements to meet him at Paine's shop. Here, then, at the appointed time Edison found the General, Professor Morse, Governor Cornell and others who had been invited. When the show was to begin Paine connected a battery wire with what were supposed to be the terminals of the motor. The motor began to spin and one of Paine's men began to saw large logs. Though old Professor Morse was so excited that he exclaimed: 'I am thankful to live to see this day,' Edison was incredulous. He began to examine the motor as best he could, since one part was boarded up. Holding his hand on the iron frame, he noticed a sort of throbbing that was in unison with the exhaust from a steam engine. He called this to the attention of the General, who then tried the same experiment. Paine simply used the battery to signal to a confederate below the floor to switch a belt from a steam engine on or off the motor.

An illustration of the Paine electric motor taken from his patents, Nos. 103,228 and 103,230, may be seen in the *Scientific American* of June, 1871. Patents, of course, seem necessary when such schemes are foisted on the public, for they tend



Page's electric motor (1851).

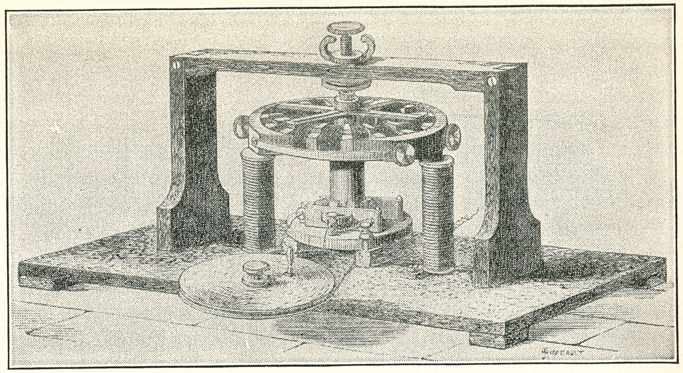
to boost the credulity of the victim. Paine was soon exposed, but many others bobbed up with wild-cat notions. The musty newspapers and journals of those days reveal how surprisingly many were working on this alluring problem, all trying to use electricity for propelling boats and carriages, as well as for all other possible purposes.

In 1875 George F. Greene, a mechanic of Kalamazoo, Michigan, constructed a motor on antiquated lines that received its current from a battery through an overhead line and used the rails as a return. His efforts were unsuccessful.

Thus before Gramme and Siemens there existed no possibility of using current in a large commercial way. Years went by slowly, during which the arc light system gradually developed, and in 1878, the year of the Paris International Exhibition, Edison expounded the possibilities of incandescent lighting. In 1879 he proved beyond doubt its practical and commercial application, and advanced the construction of generators, or motors, to a stage never before thought possible. By fine reasoning and with a good measure of common sense, he constructed a dynamo having an efficiency of 90 per cent as against the 40 per cent of the best machine of previous make—and this contrary to essential ideas which others had thought mathematically correct.

Edison, after much research in different kinds of iron, employed soft, good iron in the construction of his field magnets; he studied air gaps and made perfect magnetic joints, using a cross section that astonished others. He studied the various effects of many and few windings on the field magnets and found the saturation point for a given cross section. In fact, he had studied the effects of ampere turns at a period when men's minds never considered them seriously, or rather knew nothing about them. He gave us the shunt, or high resistance field coil. He constructed the low resistance armature, which, though it provoked criticism and derision at the time, was later recognized as embodying new and true fundamentals. His work on the windings of field magnets comprises series, shunt and compound methods. This was all done in 1879.

In 1880, for the first time in electrical history, he applied the compound wound motor (or dynamo) in practical work—specifically in his Menlo Park electric railroad experiments. From an electrical point of view, Edison's work on electric transportation settled the question of the commercial feasibil-



Pacinotti's great discovery of the proper armature winding and commutator (1860). Ten years later Gramme adapted it to commercial use.

ity of electric traction. Good mechanical engineers had next to do their part by applying Edison's principles.

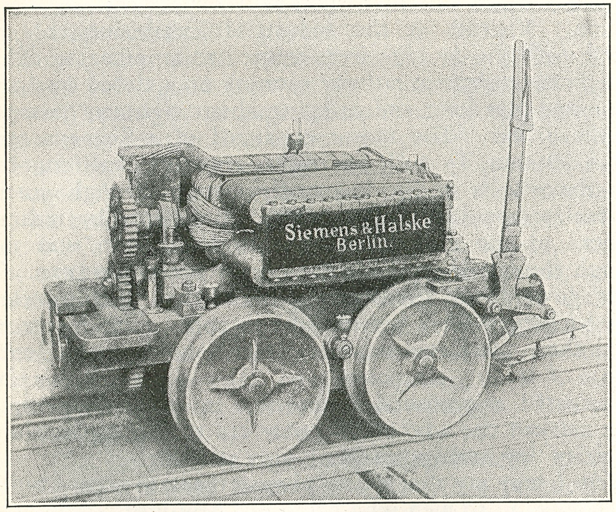
At this same time Dr. Werner Siemens, the veteran electrician of the pioneer firm of Siemens and Halske, of Berlin, Germany, made the first successful experiment in electric traction. Visitors at the Industrial Exhibition that was opened at Berlin in 1879 were treated to an amazing exhibit—the Siemens electric railway running on a closed oval track a thousand feet long and carrying about eighteen passengers and the driver. The motor consisted of a Siemens series-wound dynamo, Type D, having its armature shaft connected with the wheels of the locomotive truck through gearing. An insulated middle rail supplied the current (by means of brushes) to the electric motor and the return was made through the outside rails on which the locomotive ran. The motor gave about three horsepower when running eleven miles an hour with a tension of 150 volts. The locomotive pulled three platforms on wheels, each having two benches capable of seating six passengers. The success of this show road created a profound impression in engineering circles, for it marked the advent of a new era in the application of electricity for transportation.

Here I may say that we are always ready to accord historical recognition to men who bring out new ideas though they may be unable to do anything practical with them. On the other hand, the chief merit belongs to the man who makes a

success of his work. Thus we give to Dr. Werner Siemens the honor he deserves of being the first to show what electricity could do in commercial traction. The same ethics fit the incandescent lamp controversy: while we know that the problem was solved by Edison, yet we mention historically the men who labored before him and yet failed to realize practicable results. Man's objective in this world is to advance the well-being of humankind and to bring within the reach of all what has only been enjoyed by the few.

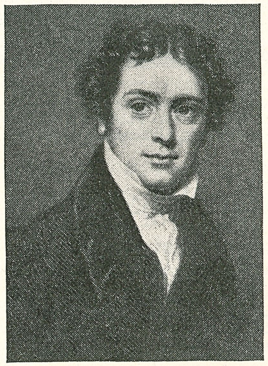
It was Dr. Werner Siemens' initiativeness that brought electric traction definitely before the world, for he was the first to employ current generated by a series dynamo used as a motor. His apparatus, at that period considered modern, convinced everyone that at last the problem had been switched onto the right track. That little railway proved how futile all work on the motor had been before 1879.

Siemens' 'series machines' were also used for series arc lighting. Now, examining the picture of his motor, the electrical engineer will see at a glance how inadequately that motor was provided with iron for the poles and cores.



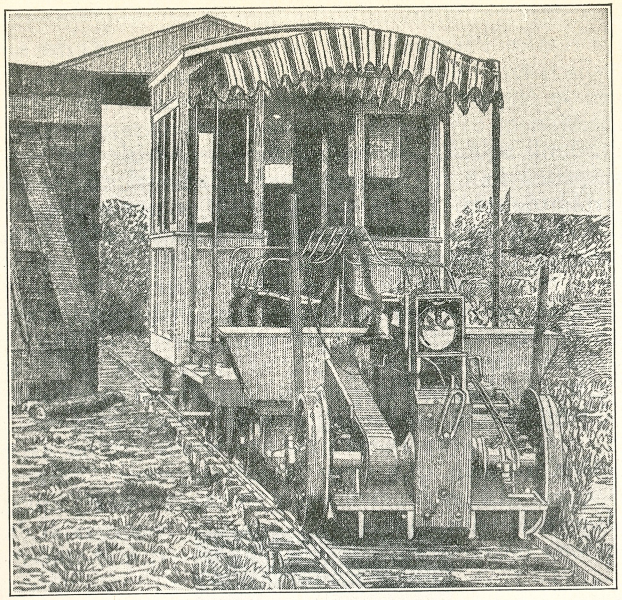
Siemens' electric locomotive of 1879. It was known as Type D, and gave 150 volts. A series-wound machine, it ran in one direction only. Used in series arc lighting.

Notice also that it used the least effective magnet core winding, which was long and of hardly any breadth. What was modern in 1878-79 was antiquated in 1880, for Edison's regeneration of the dynamo worked a revolution in the art. After a look at Edison's electric locomotive of 1880, we are not surprised that his machine had an efficiency which was more than double that of any dynamo or motor previously built. The Edison constant potential system also fulfilled the demands of electric traction.



MICHAEL FARADAY

Engraved by J. Cochran from a painting by H. W. Pikersgill, Royal Academy. Exhibited at the Royal Academy in 1829—two years before Faraday's discovery of magneto-electric induction.



Drawing of Edison's electric railroad published in the Daily *Graphic* in 1880. Note the manner in which the belt was used. The original locomotive and cars are now in Greenfield Village.

LXV. The Electric Railway

(PART TWO)

LET us return again to Menlo Park. It was in the latter part of January, 1880, at a time when Edison was already deeply engrossed in carbon filament experiments, that he resolved to take up as a sort of recreation this new problem of the utilization of electric energy for motive power, and especially for locomotion purposes. The idea had been in his head ever since the time out West when, watching men at work in the mining regions, he had exclaimed to Professor Barker: 'Why cannot the power of yonder river be transmitted to these men by electricity?'

In those early days he had often argued with Upton on the advantages of counter-electromotive force in a motor such as the small unit that drove the sewing machine, and the

one pumping water down at the Edison homestead. The latter machinery had been satisfactorily substituted for a windmill whose vanes had been thrown out of gearing. (1)

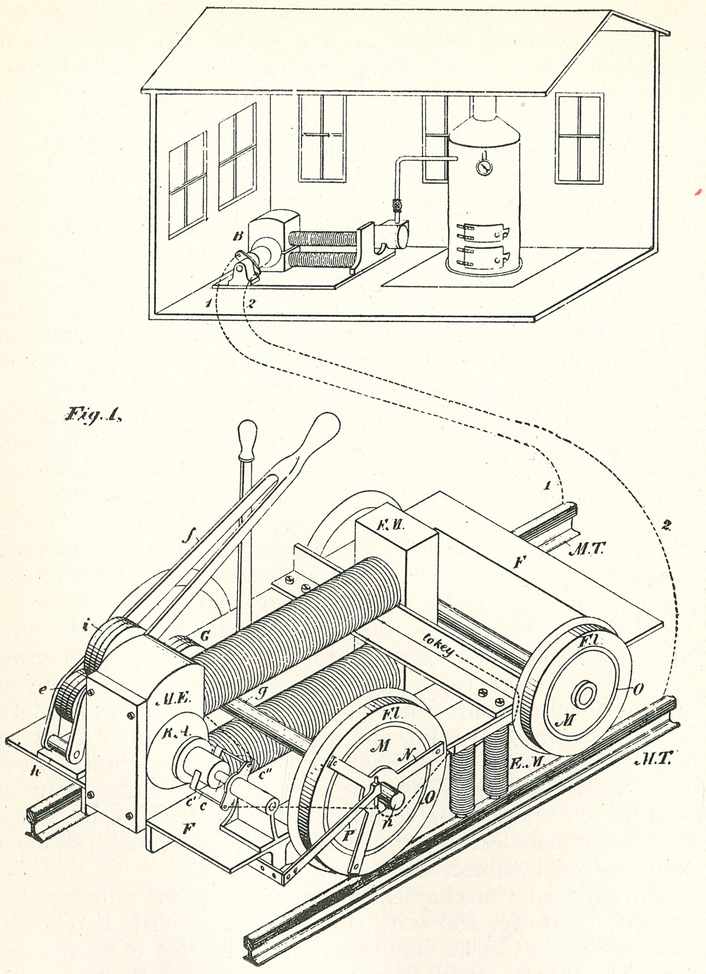
Hardly anything was known in those days of counter electric motive force. Men argued vehemently against it; they proclaimed it an evil propensity that machinery should be rid of, for it acted like resistance, and resistance was considered bad in any form. Even Sawyer, who like Swan had made a rod of carbon incandescent and had called it a lamp, once made the following comment on Edison's lamp: 'Mr. Edison has not yet learned that the greater the resistance of a lamp, the greater the power required to operate it.'

Any amount of such nonsense was abroad in those days everywhere but at Menlo Park. As I have already said, only Edison knew how to juggle with volts and amperes and consequently also with resistance, to the complete dumbfounding of his rivals. Counter electromotive force was considered a blessing by Edison who desired a good amount of it in his motors: he said it acted as a safety valve and regulated the flow of current accordingly as the motor was doing more work or less work. It was small wonder that Edison's divine reasoning powers flabbergasted many men of science, who found they had to unlearn what they thought they knew. We owe a great deal indeed to Edison's researches on the important subject of counter electromotive force.

Little was known, either, of the electric motor; for electricity was still an enigma to all and a great surprise to the masses. Even today much information is still wanting on the phenomenon. Thus it was that Edison resolved to lay an experimental track and study the problem of traction from the electrical standpoint so interesting to him. Notwithstanding his eagerness, the exhaustive attention required by the very important technical and commercial problems involved in his electric light development prevented him from going into the subject as he desired.

He engaged a mechanical engineer, however, whose name was J. L. Hornig, and with him as well as with Batchelor, Upton, Kruesi, Clarke, and others, the building of an electric locomotive was often discussed. Edison laid before them the advantages of his dynamo over all others, its low internal

(1) This motor may now be seen at the Edison Menlo Park laboratory at Dearborn, having been presented to Henry Ford by the Association of Edison Illuminating Companies and the Edison Pioneers.



Patent drawing of Edison's electric railroad and locomotive showing friction gearing. Filed June 3, 1880. No. 475,491.

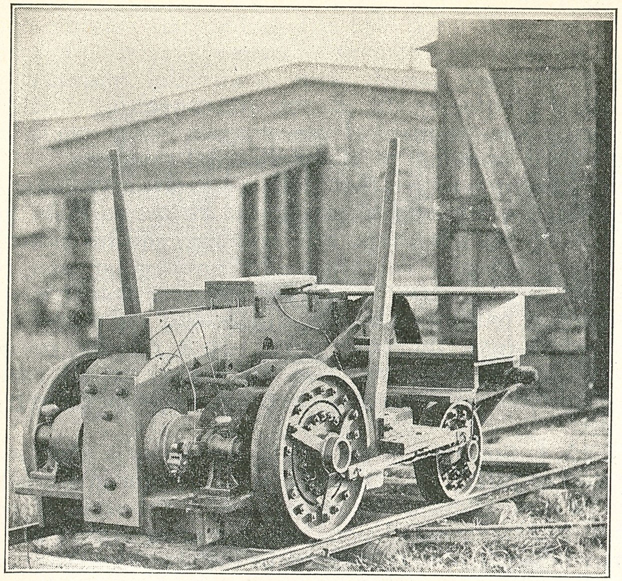
resistance and its consequent efficiency; since a dynamo is equally as good when used as a motor, here was the opportunity for utilizing the most efficient apparatus in existence. Able to generate current with commercial efficiency, and possessing a motor equally efficient in reconverting the electrical energy into mechanical power again, they could now devote their attention to the mechanical problems.

We must not forget that Edison's great contribution to the generation of electrical power was the *low resistance armature* dynamo and compound field winding, and his system of constant potential. All other experimenters at that time were working the series system and insisting that it was impossible ever to devise a way in which light and power could be supplied from the same wire. Thus the *low resistance armature generator, or motor*, was the answer to all coming problems in the distribution of electrical energy for commercial purposes.

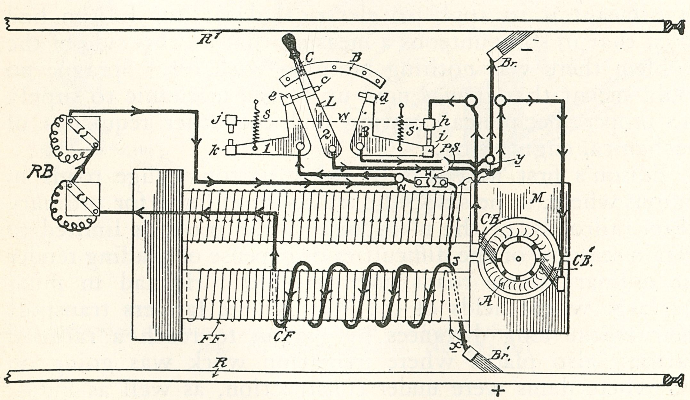
Frank J. Sprague, in an article appearing in the *Century Magazine* of July, 1905, expressed the situation in a nutshell when he said: 'Edison was perhaps nearer the verge of great electric railway possibilities than any other American. In the face of much adverse criticism he had developed the essentials of the low-internal-resistance dynamo with high-resistance field, and many of the essential features of multiple-arc distribution, and in 1880 he built a small road at his laboratory at Menlo Park.'

When Sprague inserted the word 'perhaps' he could never have meant it to apply to electrical data; for Edison had given that in so bounteous a measure that on this side of the problem there was nothing more to wish for. Sprague no doubt meant that it was now up to the mechanic to supply the proper mechanical gearing and the other requisites of mechanical engineering.

Edison's first idea was to study narrow gauge roads in regions where, as he said, 'the traffic is too light for ordinary steam railroads, or the main bulk of the traffic is limited to certain seasons, or the difficulties or expense of grading render the ordinary steam roads impracticable.' He had in mind the large wheat fields of the West where farmers transport their wheat long distances by wagon to reach a railroad station; also places where irrigation work was going on and where dams were under construction, as well as industrial centers requiring a cheap and inexpensive transportation



Actual photograph of Edison's electric locomotive at Menlo Park in 1880. It could run in both directions and was the first operated by a 90% efficient generator.

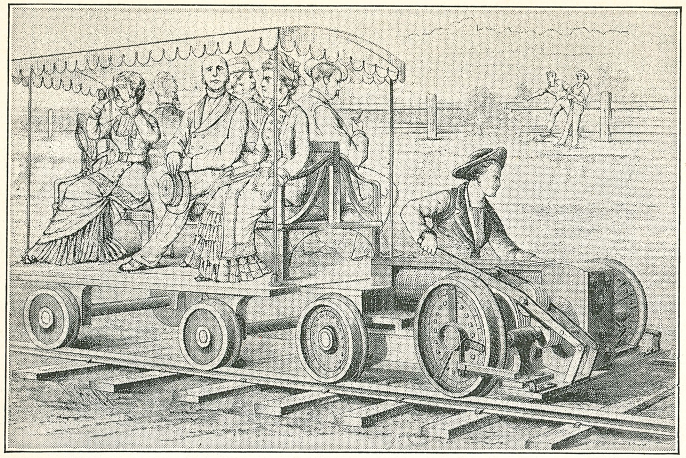


Electrical diagram of Edison's locomotive of 1880.

system in substitution for horsepower. He considered that the cheapest medium for conducting the current would be the rails, one for the positive and the other for the negative current.

Well, the mechanical tribunal of Menlo Park decided to use a friction pulley for communicating the power from the electric motor to the wheels of the locomotive. Kruesi had to make a dynamo machine similar to the three that were used for the light demonstration with the exception that its field coil was to be a high resistance shunt. The motor resembled our A-type dynamos, known in the vernacular of those days as the 'long-legged Mary Anns,' because of the long-legged field magnet cores. It delivered about sixty amperes, and was considered at that time to have an enormous capacity; in fact, it was the largest machine then known. It was rated to supply the current for about sixty 'A' lamps of the paper horseshoe kind when operating at sixteen candles (the lamps took about 0.9 amperes). The Edison dynamo could easily bear an overload of fifteen or twenty amperes. Its excellence, soon to be proved, prompted sane dynamo builders to follow in the principles that Edison had laid down.

The question of fusing this first shunt coil was discussed pro and con, and the decision finally made to insert a fuse in the circuit. It was also decided to make a switch by which the locomotive could be started or stopped, or the direction of the current could be reversed. When finished, the motor was mounted on a four-wheel iron truck, the armature end of which was in front and the shaft parallel to the axle of the locomotive driving wheels. Upon this axle, as well as on the armature shaft, grooved friction pulleys not in mechanical contact with each other were mounted. A pivoted lever having a third wheel was placed so that the wheel carried the power from the motor armature to the driving wheels whenever the lever was pressed by the operator. I may mention that when Charles L. Clarke, who was a mechanical engineer, disapproved of the friction arrangement at the time, he was looked upon, he once told me, as a dissenter and numskull. However, his day came soon. Edison divided the car wheels into two sections which were insulated from one another with wood so that the hubs were not in metallic contact with the flanges. Three-legged brass spiders were placed against the front of the flanges so that they made electrical connection with that part only, and not with the

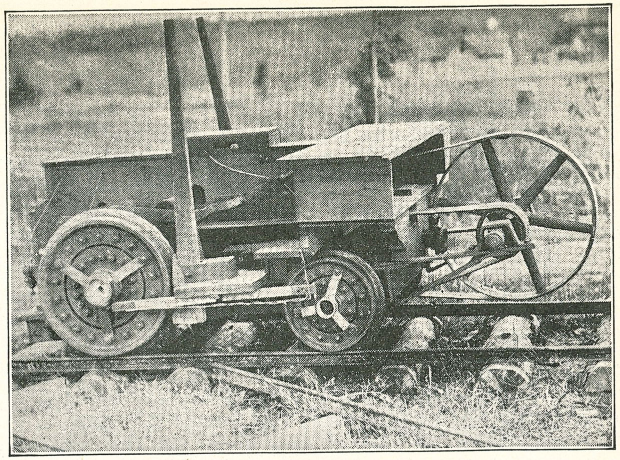


Edison's electric railroad as drawn by a *Scientific American* artist in 1880.

hubs. At the center of the spiders were metal studs supporting copper brushes, by means of which the current was received on one side of the locomotive, and on the other side led back to the other rail.

While the locomotive was being built at the machine shop, the track was laid. For this Edison chose light rails of about sixteen pounds to the foot—the gauge was forty inches. These were spiked to rough sleepers laid on the ground in hurried military fashion. Campbell, our carpenter, did this part of the work with a gang of men. The electrical connection between the rail lengths was secured by bonding them with two heavy copper wires. A little distance down the road was a trestle work that bridged over a hollow piece of ground a little more than one-third of a mile in length. The track ran from one side of the machine house toward the ravine with the copper mine, called Mine Gully.

We had at Menlo Park only three of the Edison generators, of which one excited the fields of the other two, and these two generated the current for the lighting plant. When the electric locomotive experiments were first being made, we used the current from these same machines by connecting them with the railroad tracks. The electric road was never in operation at the same time as the lighting plant, and vice



Side view of the Edison locomotive of 1880.

versa. The lighting plant generators continued to supply current at ordinary voltage for the railway experiment up to the latter part of 1880, when a new and enlarged plant was erected.

All the current used at Menlo Park was thereafter supplied from this enlarged plant. The generators generally ran during the day for the transmission of power to the lamp factory and for the operation of the electric road, each of these activities being served by different generators. The two generators for the electric road and those for the lamp factory were connected up in series, each circuit, however, independent of the other. The reason for the increased voltage was that as the tracks of the railroad had been extended to a length of about one mile, and the distance to the lamp works was about 2,500 feet, more working pressure was necessary. The generators had to be reconnected twice a day, which work I did, as my notebook attests. The dynamos were generally connected with the lamp factory and the electric road in the morning, and then were all connected back with the multiple arc circuit for exhibition or general lighting in the evening.

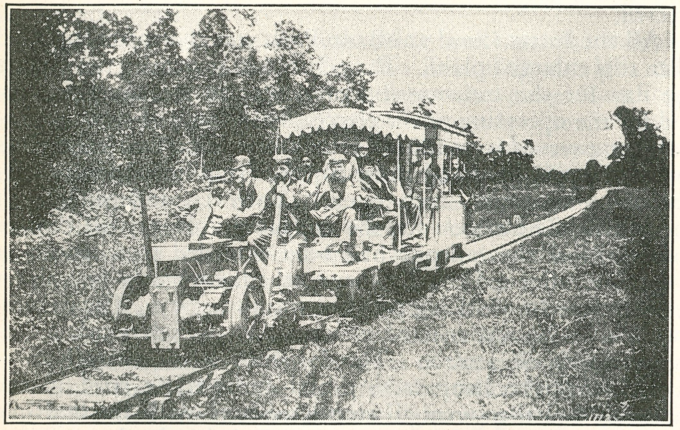
Let us now proceed to the first experiment with the electric locomotive having a friction gearing. The great day of the trial happened to fall on the 13th of May, 1880. In the

presence of newspaper men and other guests from near and far, the 'locomotive' was taken from the machine shop, placed on the tracks, and coupled with a trailer having two benches and protected from the sun by an awning roof.

Of course, as many of the 'boys' as could find foothold crowded on—about twenty in all; I noticed, however, that our friend Clarke was not one of the passengers. It was somewhat late in the afternoon, about 4 o'clock, when the thrilling moment came for the signal to start. The current was switched on, and amid cheers, hurrahs and the waving of hats and handkerchiefs, the little train started up.

It was the first time that America or any other place had ever witnessed such a sight—an electric railroad operated with a commercially efficient generator and shunt motor. The locomotive picked up speed and we all glided along to the end of the line with excitement and buoyant hopes.

When the order 'all aboard' was given for the return trip, Batchelor applied the lever so violently that one of the friction wheels burst and disabled the locomotive. Of course, we all walked back, pushing the train with us, and when we arrived were received by an anxious and inquisitive crowd



Edison's Menlo Park electric railroad taken in 1880. Charles Batchelor at throttle and to his left is J. L. Hornig. Others who took that first train ride were: Charles Hughes, Tom Logan, William J. Hammer, Francis Jehl, Alexander Mungle, H. V. Campbell, John W. Lawson, William Mills, John Ott, John Randolph, George Hill.

who all (but Charlie Clarke) asked: 'What happened?' Clarke surmised what had taken place but said nothing.

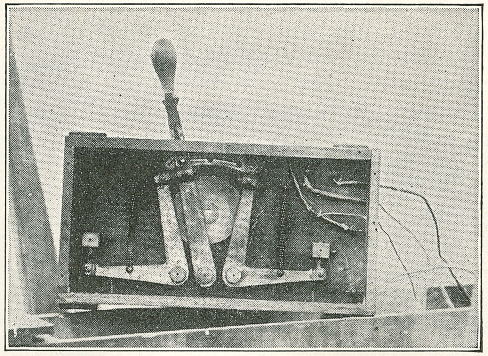
In order to continue his study without delay, Edison gave orders to Kruesi to have the locomotive fixed up with a leather belt transmission. A pulley on the armature shaft was connected by a belt with a larger one mounted on a countershaft at the rear of the locomotive truck. This countershaft had a second and smaller pulley that was belted to one on the driving wheels by means of a slack belt. The latter could be tightened by a lever arrangement and pulley somewhat similar to that used in the first experiment; with this the operator was able to start, stop and regulate the speed of the locomotive. Of course, the shunt wound motor and the electrical reversing switch all remained the same. The leather belt arrangement allowed us to start the motor as before and then as it gained speed and the pulley lever was gradually pressed down, we could tighten the belt, start the locomotive and regulate its speed. Slipping occurred, of course, and it was soon learned that the operator had to exercise judgment in throwing the power onto the driving wheels to prevent damage to the armature. While it was evident that belt transmission on a locomotive was mechanically crude, it sufficed for Edison's principal object, which was to study the electrical phases of the problem. He, as well as Kruesi, Batchelor, Upton and Clarke, had his hands full of other matters and could spare little time to the mechanical problem of transmitting the power to the driving wheels. And neither Hornig, the mechanical engineer engaged to work out the problem of gearing, nor those who followed from the New York office later, ever offered anything better.

Edison, of course, experimented with the little railroad now and then as time permitted. In our first trials with the leather belt, the shunt of the motor was connected directly across the tracks with a primitive fuse inserted. The main current leading to the motor armature was served by some resistance boxes in series that could be plugged out at will. These boxes were inconveniently placed, some under the driver's seat and some near the foot rests and platforms—in fact, we had more boxes than were needed for starting the motor. While considering the arrangement, an idea struck Edison—a real *bona fide* idea, and not the haphazard one attributed to him in certain publications. He had some of the boxes replaced with a heavier one specially built, which could also

be easily plugged in or out by the driver. In series with this resistance and armature apparatus, he wound one leg of the field magnet of the motor with heavy copper wire—the reason for which was thoroughly comprehended by the young but experienced electrical sleuth. He saw how the motor slowed down when going upgrade and he knew how much it would be benefited by those series windings, which, moreover, could be plugged in or out as desired. Thus from a shunt motor was developed the compound type.

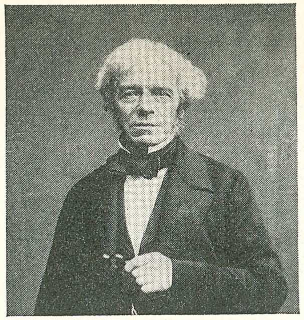
I remember that this pioneer belt-driven locomotive served our purpose as long as I remained at Menlo Park, which was until May or June of 1881. To the awning car already mentioned we shortly added an ordinary flat dump car for use in road work and a box car which we dubbed the 'Pullman,' all three of which the locomotive often pulled loaded with passengers. We also added a headlight and a signal bell. From the beginning, technical journals and newspapers brought the electric railroad to the attention of the public, and suggested its use for city transportation.(2) Railroad men from everywhere flocked to Menlo Park, among them Biedermann and my old friend Rene Thury, of Switzerland.

(2) New York *Herald* May 15, 1880; *Scientific American* June 6, 1880; New York *Herald* July 23, 1880; New York *Herald* July 24, 1880; New York *Graphic* July 27, 1880, etc.



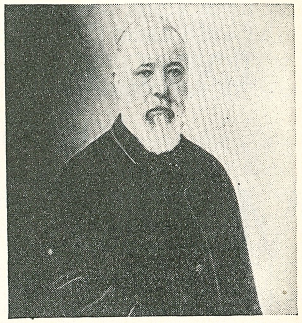
The starter and reversing switch used on Edison's electric locomotive of 1880.

Five Pioneers in the Development of the Electric Dynamo and Motor



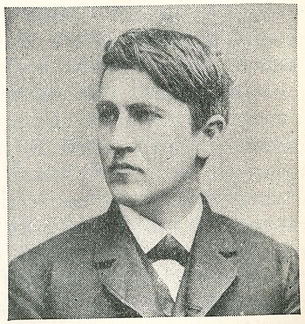
Michael Faraday, September 22, 1791—August 25, 1867.

Dr. Antonio Pacinotti, June 17, 1841—March 28, 1912.

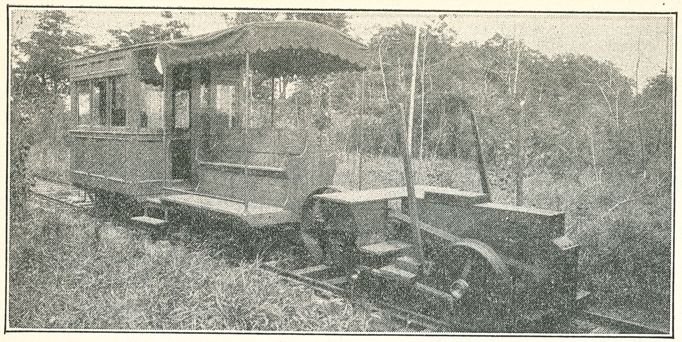


Zenobie Theophile Gramme, April 4, 1826—June 30, 1901.

Dr. Werner von Siemens, December 13, 1816—December 6, 1892.



Thomas A. Edison, February 11, 1847—October 18, 1931.



Edison's first electric railroad now at Dearborn as a part of the Edison collection.

LXVI. The Electric Railway

(PART THREE)

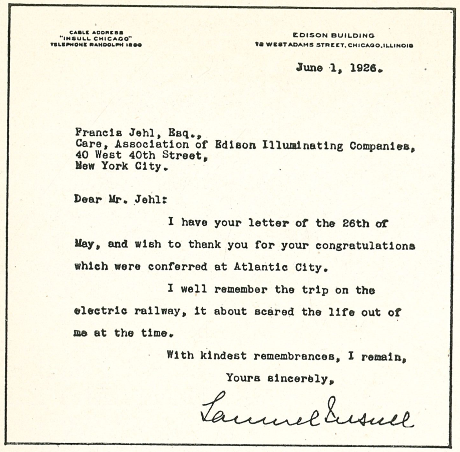
MANY were the train rides taken by the boys as well as by the numerous visitors arriving daily to see the first real electric railroad in America. Of course there were accidents but none of a serious nature, I am happy to say. One June day in 1880, my former chief, G. P. Lowrey, was taken for a ride in company with Calvin Goddard, treasurer of the Edison Electric Light Company, of New York. Kruesi, who was the driver of the engine this time, put on the 'juice' and the train sped along with a velocity that brought a protest from Lowrey as they rounded a curve. Edison, who was with the party, smiled and said it was all right. 'I'd rather you'd go slower on curves,' said Lowrey as they were about to make the return trip. Kruesi, however, who wanted to make a good showing with such important guests, 'soaked the juice' into the locomotive. As they ran a short curve the train jumped the track, Kruesi was thrown face down in the dirt and Force was shot into the underbrush after as fine a somersault as any circus athlete could turn. Edison was off in a second, laughing; it was a daisy of an accident, he said. That gave Kruesi courage; with dirt and blood over his face, he replied, 'Oh yes, it's pairfeckly safe.'

Lowrey delighted in relating this incident and in repeating with Kruesi's foreign accent, 'Oh yes, it's pairfeckly safe.'

Another incident of the kind happened somewhat later. On March 2, 1881, according to my diary, at an hour when I happened to be alone in the laboratory, a young man entered. I asked him, 'What's on your mind?' 'Oh, don't ye know? I am Mr. Edison's new English secretary and my name is Mr. Samuel Insull,' which was said with a rich London East Lombard Street accent. Now we American boys at that time were not so well-bred as our English cousins, and I, like others you may know, had hailed from the east side of New York City. However, I desired to be as polite as possible and answer in English too. ' 'Pon my word, Mr. Samuel Insull, it's mighty jolly to meet you and I shall be awfully glad to show you around in Mr. Thomas Alva Edison's laboratory,' I answered, drawling out some of the words in English fashion as we used to do sometimes during the frolics of our midnight lunch.

Well, I showed Sammy all round the laboratory, the glass house, the machine shop, and finally took him to the shed where the electric locomotive was. He wondered at the little engine that could haul those three trailers full of people and asked whether the machine was 'in operative condition.' 'Certainly, my dear sir,' I answered, and asked whether he would like a ride. 'I should appreciate it,' said he. The engine driver at the machine shop started the engine for us. We just took the locomotive without the trailers, I being on the operating side of the machine and Insull on the other side near one of the brake handles. I switched on the juice and soon we were going at the rate of thirty miles an hour. Insull seemed to enjoy it. When we reached the end of the line we stepped off for a few moments and looked at the remains of the old copper mine.

As we were taking our seats for the return trip he asked whether I had ever heard of 'The Flying Scotchman,' England's crack train. I replied that I had, and he mentioned that, of course, its speed was nothing to compare with the speed of this electric one. 'Oh it's speed that you are hankering after!' I replied in a dry way that made him suspicious. The boys at Menlo were always ready to accept even the hint of a challenge involving the work of Edison, as I believe Bernard Shaw has already testified. I started the motor and


CABLE ADDRESS
"INSULL CHICAGO"
TELEPHONE RANDOLPH 1280

EDISON BUILDING
72 WEST ADAMS STREET, CHICAGO, ILLINOIS

June 1, 1926.

Francis Jehl, Esq.,
Care, Association of Edison Illuminating Companies,
40 West 40th Street,
New York City.

Dear Mr. Jehl:

I have your letter of the 26th of May, and wish to thank you for your congratulations which were conferred at Atlantic City.

I well remember the trip on the electric railway, it about scared the life out of me at the time.

With kindest remembrances, I remain,

Yours sincerely,

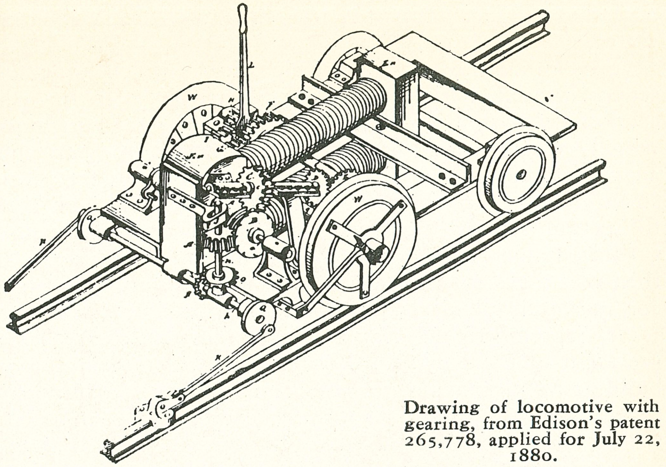
Samuel Insull

Letter from Samuel Insull referring to his ride on the first electric railway with Francis Jehl.

gradually plugged out the resistance. We rounded the curve without mishap and were flying along at a speed that scared the life out of Insull who, holding fast to the brake handle, begged me to slacken up. In the faint light that prevailed, something appeared on the track ahead of us, just at that weird spot where the trestle work was. I cut off the current instantly and applied my brake so suddenly that the handle broke. At the same time a bunch of feathers shot upward. I reversed the current for a second several times while Insull pulled at the brake, and so we managed to arrive at the station without a crash. Insull felt greatly relieved at setting his feet on *terra firma*.

The incident might have turned out far more disastrously to us both than that 'pairfeckly safe' one of Kruesi's. I learned on the following day that the flying feathers were from two turkeys belonging to Andrus, the pattern maker, who complained that he was now going to be 'fed up' for a week or so on turkey meat. He admitted however that a track was no proper roosting place. And Insull admitted that an electric locomotive could attain a surprising speed and would no doubt compete with the steam one in the future.

The length of our road was eventually increased from a third of a mile to about a mile, and the little railway was used to haul all the necessary material for it. After several sharp curves and steep grades, the new road terminated at a small stream with a shack near by which we called 'Pumptown.'



Drawing of locomotive with gearing, from Edison's patent 265,778, applied for July 22, 1880.

During the days of Edison's grand final demonstration of the lighting system in the winter of 1880-81, operation of the railroad was suspended because the locomottve had to be stationed at this shack for the following reason.

In preparation for the demonstration the capacity of our generating plant had been increased from three to eleven dynamos, one of these machines being the exciter for the other ten and its own field. So much more energy was consumed by this machinery and therefore so much larger a quantity of water that our well was proving insufficient for the demand upon it. One evening Kruesi ran into the laboratory all excited and said that the engine would have to be stopped because the well was dry. 'All right,' said Edison, and called for Charles T. Hughes(1), who was told to take the first train in the morning to New York and come back with a mile of piping. When he returned with it, all hands were put to work and the pipes were laid in no time. A pump was also obtained and connected up with the locomotive, which thereafter kept the well supplied with all the water

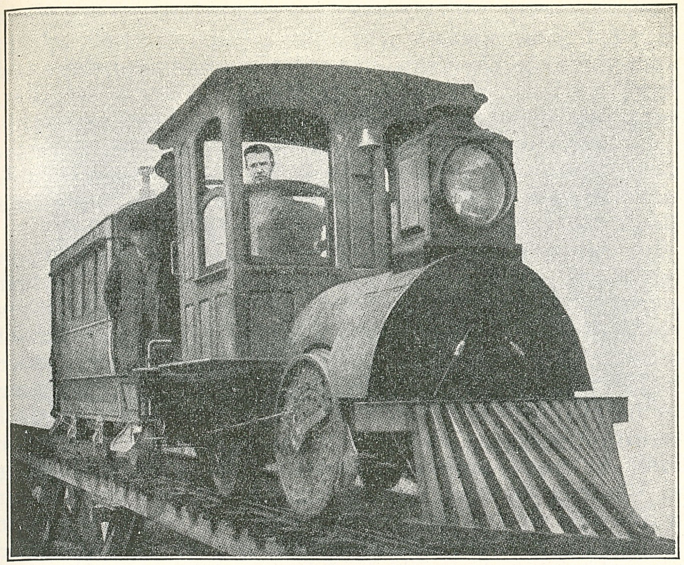
(1) Here I wish to correct a misunderstanding regarding Hughes, a dear friend of mine. Hughes joined our staff early in 1880 as purchasing agent; being a commercial man, he at that period had nothing whatever to do with the electric light or the electric railway, despite statements to the contrary in certain books and journals. When Edison, Upton, Batchelor, Kruesi, Clarke and others left the laboratory, we had no need for a buyer and Edison retained Hughes at Menlo Park to demonstrate the road to visitors, for Hughes was a congenial sort and well suited to that work. Later he became agent of the Edison company at Syracuse, and after the organization of the General Electric Company, its eastern manager.

necessary. This pump was housed in the shack referred to above.

Edison had now solved the electrical problem that he had set for himself, which was, in his own words 'to furnish an economical system of electromagnetic railways or tramways which, while useful in any locality, will be particularly adapted to regions where the traffic is too light for ordinary steam railways or where the main bulk of the traffic is limited to certain seasons, or where the difficulties or expense of grading render ordinary steam roads impracticable.' Here then was a system that an ordinary day laborer could handle and in which the mechanical parts were as simple as could be.

In September, 1881, at the instigation of Henry Villard, president of the Northern Pacific Railroad, Edison agreed to build at Menlo Park a new line with improved equipment in order to make a final test of its practicability as an auxiliary wheat transporter in Dakota. If the test showed that the wheat farmers could bring their produce from the interior to the main lines of the steam railroad cheaply, Villard would pay the expenses of the new trial road.

At this period (1882) Edison was already established at 65 Fifth Avenue, New York City, and was intensively engaged there in the commercial introduction of his system of lighting; demanding attention besides were the Edison Machine Works, the Edison Tube Works, the Lamp Factory, Bergmann & Company and lots of other things. It was impossible for him to give his personal attention to the new traction experiment in the real Edisonian manner. So the work at Menlo Park was given mostly to others to carry out. More care was taken in preparing the roadbed, which was about three miles long and had three sidings and two turntables; along its course were also several trestles. More care was taken in insulating the rails. Fundamentally, there was no change in the two new electric locomotives—the field was compounded with shunt and series windings as in the old one. In appearance, these engines were different, however, being camouflaged to resemble their steam brothers from a distance—each had cowcatcher, bell, headlight and cab body. The work was considered satisfactory by Edison from the theoretical point of view, though it reached no practical result because the Northern Pacific went into the hands of a receiver. Villard had advanced about $35,000 to $40,000 toward the trial road, which money Edison refunded to him later on.



Edison in the cab of his electric locomotive of 1882.

Like the old road, the new, of course, carried many thousands of the visitors who came to Menlo Park.

In 1882 M. Clovis Dupuy, an engineer in charge of the bleaching grounds at Le Breuilen-Ange, constructed an electric railway that received its current from Faure accumulators placed in a tender attached to the engine car. The rails had a length of about 2,000 meters.

In the early part of 1883 a company was formed under the name of the 'Electric Railway Company of America' with a capital of two million dollars, their object being to develop and exploit the patents of Edison and Stephen D. Field. Edison was only consulting electrical engineer. In June, 1883, their electric railway was exhibited at the Chicago Railway Exposition, and later in the same year at the Louisville, Kentucky, exposition. In both places it seemed to be a great success for it attracted crowds and enthusiasm ran high. It gave an earnest impulse to many other brilliant men whose names are today incorporated in the history of early electric traction.

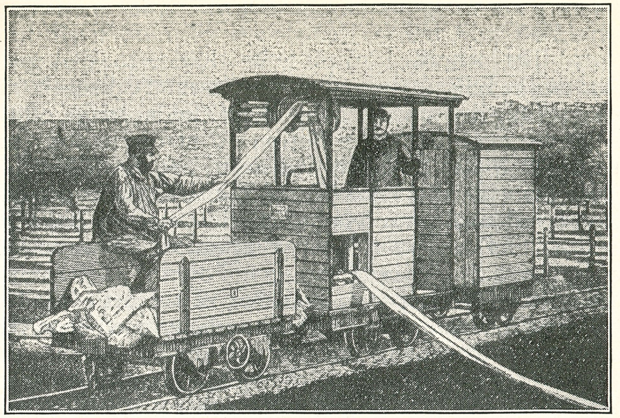
In 1890 because of internal dissensions between the Field and the Edison interests, the company assigned its Edison patent rights to the Edison General Electric Company, and a few years later, in 1897, it went into voluntary dissolution. That ended the career of a company that once held the brightest prospects of the electric traction interests in America. Its failure, as we know, was due to neither Edison nor Field. We know also that no leader can succeed with dissenting followers.

In Europe the pioneer Werner Siemens lost no time in clinching his success. I have already mentioned his first electric railroad in the Berlin Exposition of 1879 with its series motor. On May 16, 1881, he opened his first commercial electric railway (Grosslichterfelder) connecting the Cadet School with the 'Anhalter' railroad station. In this same year he exhibited an electric railroad at the Paris Electrical Exposition, showing his slot-tube trolley system. In October of 1883 he opened another commercial road between Modling and Vorderbruhl near Vienna, Austria. It was worked on the overhead slotted-tube trolley system at 350 direct-current pressure.(2) I, being already in Europe for Edison at the time and having charge of the Edison exhibit at the Vienna Electrical Exposition, was often a passenger on this road, and was surprised at how frequently the car was loaded to its utmost with the hundreds from Vienna flocking evenings to that ideally romantic place near the Vorderbruhl which was called the Bruhl.

In April, 1884, Siemens and Halske opened the electrical railroad running between Frankfurt-am-Main and Offenbach, Germany. The great pioneer firm of Siemens and Halske has always been active exponents of every division of electric traction engineering as well as of everything pertaining to electricity since the forties.

Here in America the commercial electric railway did not make such rapid strides, although Edison's experiments at Menlo Park in 1880 more than proved the inherent soundness of using electrical energy for transportation purposes. Mechanical detail still had to be worked out, and for that Edison had no time then. Outside of some show roads, the first real commercial electric road in this country was that

(2) In this same year Siemens fitted up the electric railroad at Portrush, Ireland. The current was generated through two turbines utilizing a waterfall with a drop of twenty-six feet.



Dupuy's electric tramway driven by a storage battery.

put into operation at Cleveland, Ohio, by the Bentley-Knight Company in July, 1884. Leo Daft built one at Baltimore in 1885, and Van Depoele one at Scranton, Pennsylvania, in 1886. Roads were also opened at Binghamton, New York, and Appleton, Wisconsin, in 1886, and at Montgomery, Alabama, in 1887. The Bentley-Knight Company put in a road at Woonsocket, Rhode Island, in 1887 and at Allegheny City, Pennsylvania, in 1888. In 1888, the Richmond, Virginia, road was built by Frank J. Sprague. It can be asserted that by that time electric railroading, although yet in a crude state, was an established institution both in America and in Europe. American push and enterprise soon placed the American trolley in almost every quarter of the globe.

The mention above of Leo Daft reminds me appropriately of what he once said about the multiple arc system of illumination in an address given before the New York Electric Light Association at Delmonico's on April 28, 1881. 'This whole system of illumination as now practiced,' said he, 'is a financial fallacy . . . I am free to admit that the minute subdivision obtained by the Edisonian, Swan (3) or Fox sys-

(3) Daft was evidently not familiar with Swan's work, for the latter had *no system*, but always based his contention only on a low-resistance carbon rod lamp and talked of using 10, 20, 50 or more in series. More than that, his lamp had no endurance and went up in soot. Only when Edison had first showed the way in 1879 did others know how to make a lamp.

tems is a great desideratum but this gain cannot bridge the financial gulf . . . .'

Daft, like others, learned later that even trolleys are worked on the Edison multiple arc system and that each motor represents only a translating device in the language of those days. If we were to sum up Edison's contribution to electric traction, we would find that it was so fundamental that it diverges into all the branches of the art where current is generated and used; we would find that electric traction is but a part of the whole. A few instances are sufficient to show the basic character of that grand master's achievement, without which the separate branches of the art of utilizing electric energy would all be totally inefficient and deprived of commercial utility.

Edison was the first to give us a low-resistance dynamo-electric machine.

Edison was the first to give us a dynamo-electric machine with a commercial efficiency of 90 per cent.

Edison was the first to give us a stabilized commercial system of parallel current distribution at a constant potential.

Edison was the first to propose and give us a central station where current was generated to be delivered commercially to outside premises.

Edison was the first to give us definite ideas of the laws that dominate the transportation of electrical energy commercially.

Edison was the first to give us a parallel supply conductor network with feeders.

Edison was the first to give us the efficient commercial electric motor on 110 or more volt parallel circuit. He also in 1880 operated the first compound-wound motor.

Edison was the first to recognize the beneficial influence of counter electro-motive force in a motor.

Edison was the first to give us a practical and commercial incandescent electric lamp.

Edison was the first to give us the metal fuse and electro-magnetic cut-out for protecting lines.

Edison was the first to give us a dynamo-electric machine of huge size connected directly with the steam engine without belting.

Edison was the first to give us a system in which motors mounted on two or more cars could be controlled from one car by means of a master controller.

Edison was the first to give us a motor-generator system for current distribution by translating current from high to low tension. (Patent Nos. 265,786; 278,418; 278,516.)

Edison and Dr. John Hopkinson were the first to give us the multiple wire system (with three or more wires) for energy distribution.

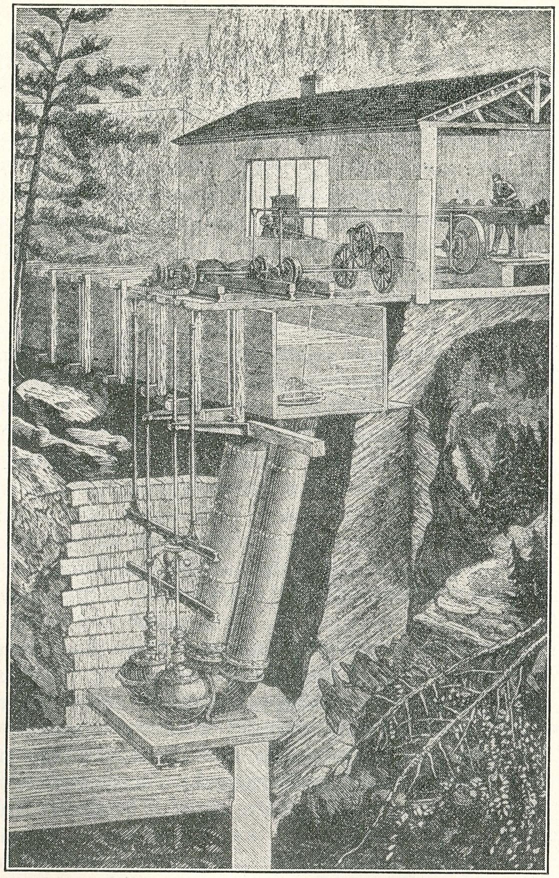
Edison was the first to give us a practical electric meter that continued in commercial use for more than a decennium.

Last but not least, *Edison was the first to give us* the principles of central station regulation, and also the first to employ remote-control, a system of wiring with distributing boxes, and a system of underground electric tubing with junction boxes, house connections, sockets, switches and other accessories. In fact, Edison was the first to harness electricity and make it a universal servant to mankind.

Thus we find in these sixteen Edisonian points the fulfillment of the electrical commandments. In these sixteen points Edison gave us the key that opened the door to practical and commercial electricity in all its aspects. No wonder that an English electrical journal at the time said: 'A few years ago when Mr. Edison wished us to understand that "beaconlike" he had taken all electrical science as his province and his alone, the English, and still more, the American journals were setting their readers agape at the wonders to be wrought for us by the magician of Menlo Park . . .'

That is just what he did, and they unwillingly sensed it. Today those sixteen points still hold good and with their imperial sway have established more firmly than ever the structure that the Menlo Park magician at the time raised. Edison and the work represented by that name, form the electrical colossus which upholds all industry of today. Yes, other illustrious men have arisen and developed the fundamentals that he uncovered, and still others have struck out in new paths which after all are being or will be found directly or indirectly intertwined with the Edisonian conceptions. What would happen if we were to wipe out the sixteen Edison points? What an electrical cataclysm would result in the whole of industry!

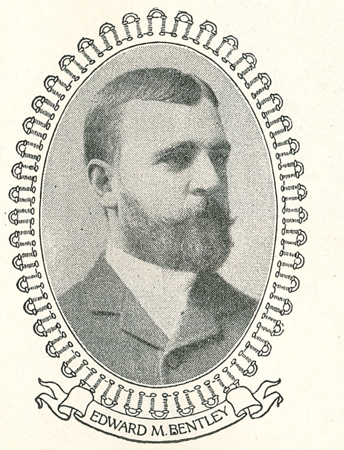
Edison was advanced in his mentality, foresight and common sense at that time far beyond most men, even if they had the title of this or that. When their reasoning did not coincide with his, they were likely to criticize him the more be-

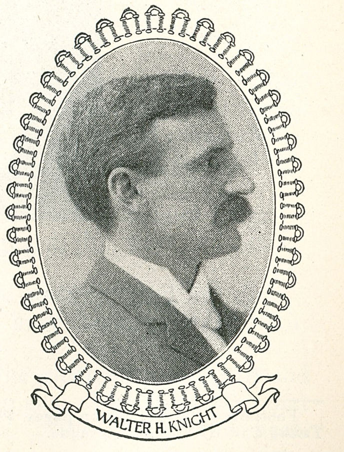


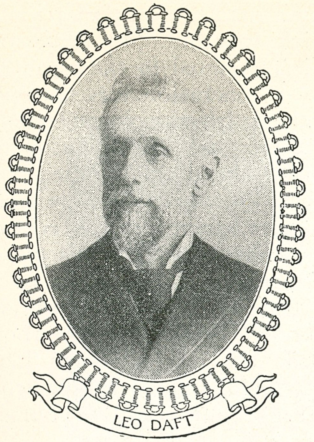
The turbines at Portrush, Ireland, that drove the Siemens generator which supplied current for the Portrush electric railway.

cause he did not possess one of their man-made appellations. It's an old saying the crows stick together. In Professor Morton's report on the electric light printed in the minutes of the Franklin Institute in 1880, a conclusion was reached that 'economy cannot be obtained by the incandescent method.' Even that brilliant engineer and electrician, Herr Von Hefner Alteneck, who invented the drum winding for the Siemens dynamo, gave a rather luke-warm recognition of Edison's work. At a meeting of the Berlin Electro-Technical Society on March 24, 1880, he referred to Edison's glow light as follows: 'Even if the American's labors come to a practical result—a thing which was by no means certain, judging by what has been made known on the subject—they could not by any means supersede the results which had already been accomplished, but would simply supplement them, and if they did come to anything, they would, of course, be welcomed by all electricians.'

Sir William Henry Preece, chief of the British Post and Telegraphs once said that he 'did not think that the telephone would be an instrument of the future and be largely adopted by the public.' He made the same forecast about the Edison light. If I were to go on and give you the opinions of other celebrated men of those days, you would be surprised how few had the vision to comprehend the work that Edison was doing.

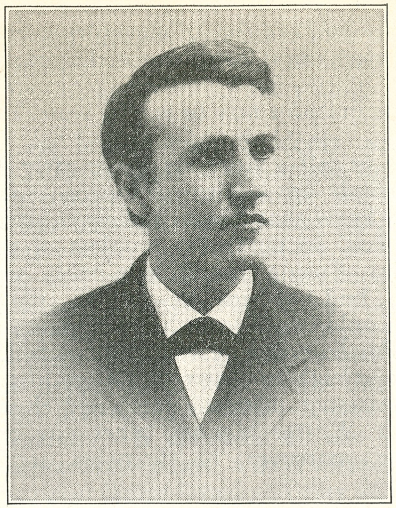






FRANK J. SPRAGUE

Footnote—Illustrations on pages 599 and 600 are taken from '*The Story of the Trolley Car*' by Frank J. Sprague.



—Courtesy of Miss Marietta Wadsworth.

EDISON in 1878.

LXVII. World-wide Hunt for Best Material

I HAVE shown with what disciplined routine Edison attacked the problem of making a practical incandescent lamp which would possess the qualities and requirements necessary for use in his proposed system of parallel distribution.

In October, 1878, at the very time when he was planning the distribution of electrical energy as light, heat and power, he said:

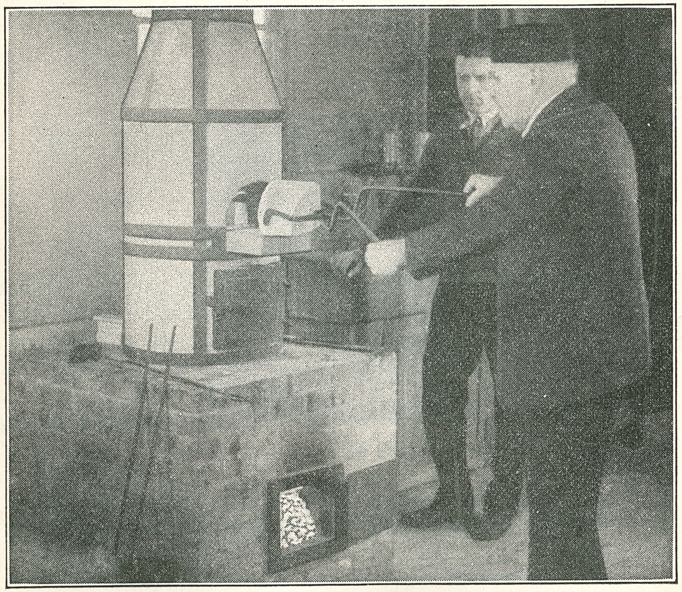
'When it is known how I have accomplished my object, everybody will wonder why they have never thought of it, it is so simple.

'I have discovered how to make electricity a cheap and practical substitute for illuminating gas. The same wire that brings the light to you will also bring power and heat.

With the power you can run an elevator, a sewing machine, or any other mechanical contrivance that requires a motor, and by means of the heat, you can cook your food. The dynamo electric machine may be run by water or steam power at a distance.'

That was too tall a story for those early day scientists. They considered it an insolent intrusion on their prerogatives; for they knew that Edison had never attended a college nor been 'trained' to unravel a problem of such intricacy. In fact, the idea of using electricity in public service as light, heat or power, had not been dreamed of. Only one man in their opinion could conceive such a wild fancy—Jules Verne.

Ahead of Edison was a year of arduous toil. As we turn our kaleidoscope back to that year we see him working first on the low resistance platinum lamp and then on the high resistance one. We see him try other rare or high fusion metals, which, moreover, he discovers are packed with



Francis Jehl shows how Edison worked the muffle furnace in carbonizing filaments.

occluded gases, and he finds a means of overcoming the gases. We see a new generator of electricity that returns 90 percent of the power applied to it; we see many lamps made of carbon filament.

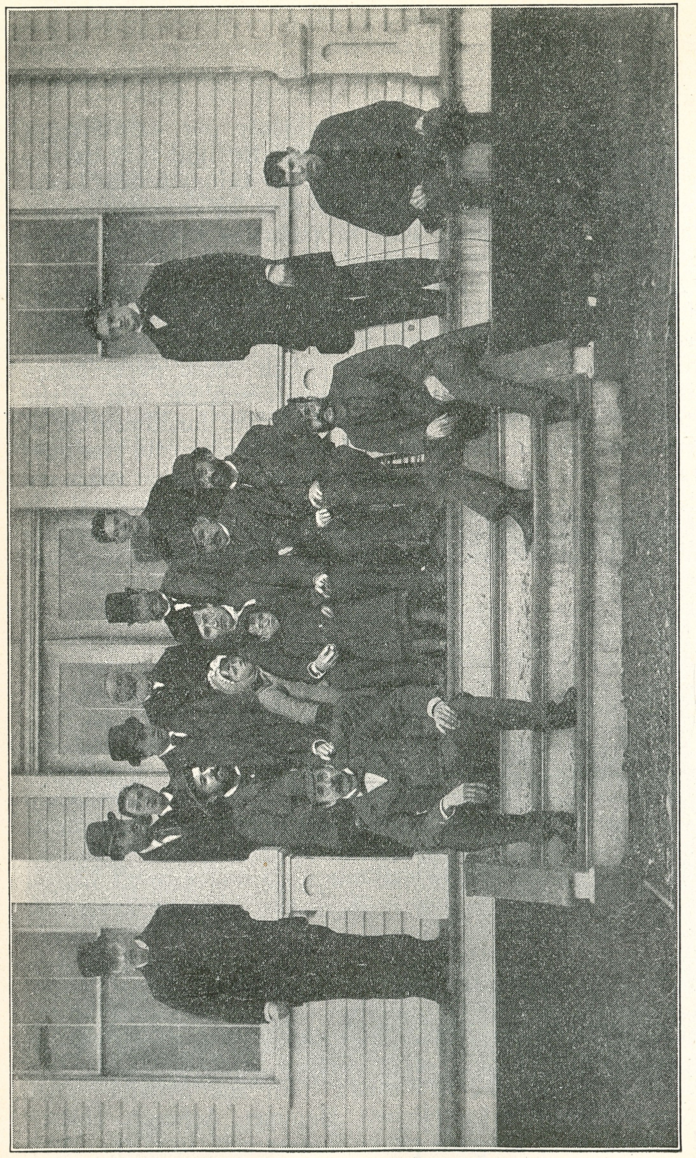
Again we are in October. Suddenly our kaleidoscope seems to have failed because of the bright light that dazzles our vision: the twenty-first of October brings a new lamp. Thus Edison has accomplished all that he promised to accomplish a year earlier; and the labors of his predecessors are laid on the shelves of historical memories.

As I have already written, the thread filament lamp was followed immediately by one whose light-giving element consisted of a piece of paper, known in history as the 'carbonized paper horseshoe lamp.' With those paper lamps Edison gave his first demonstration—it was the first in the history of electricity. It embraced all the fundamentals of distribution as practiced today. I have already told you how long these first paper lamps lasted and may add that when we began to make them in quantities, their average normal life reached three hundred hours; indeed, some reached a thousand and more. Edison was actually at that time—December, 1879—a manufacturer of incandescent lamps, *the only one*, and you can imagine how much excitement he created.

You have already heard how from time to time he himself studied each operation in the making of his lamp, and how thoroughly he worked out the process of carbonization. First he formed his filaments from the raw material and then he carbonized them. Those that worked on the problem before Edison, took carbon already made from which to shape their light-giving elements. Some had their carbons made by Carre of Paris, an electric arc light carbon manufacturer; and these were in the shape of rods.

Thus we see distinctive methods of operation, with Edison following a different course from all the others in procuring and making his carbon filament.

When at last he had concluded his investigations into carbon-making and began to make lamps in quantities, he assigned Lawson, Van Cleve and others to the job, instructing them in all the details. From that time forth it was more of a routine process than an experimental one. Likewise the newcomers whom the new-found light and dynamo lured to Menlo Park, Clarke, Howell, Hammer, Acheson, Holzer and others, were assigned places in this new activity. And



Edison and assistants, 1880. Left to right, top row, standing: George Crosby, George E. Carman, Albert B. Herrick, Francis Jehl, Samuel 'Dad' Edison, Charles P. Mott, John W. Lawson, Ludwig K. Boehm. Sitting, left to right: Charles Batchelor, Marian 'Dot' Edison, Thomas A. Edison, Thomas A. 'Dash' Edison, Jr., Charles T. Hughes, William Carman. Bottom row, from left to right: William Holzer, James Hipple, George Hill.

each of the so-called 'departments' was given its own routine.

While the new lamp and its system were being exhibited at Menlo Park (and that continued for months), Edison made a final exhaustive search for a raw material that would be more dense and homogeneous. He said, 'In God's almighty warehouse there must certainly be such a material—we have only to hunt for it.' Books on botany and catalogs were studied; Hughes, our purchasing agent, was sent to New York with a list of materials to purchase. Day by day he brought back packages of samples. He called on wholesale drug companies, agents of foreign firms, museums, colleges, and consuls of foreign nations in an effort to get almost everything in the vegetable kingdom. He also brought samples from the animal world, such as hoofs, hides, horns, and hair. Botany professors sent in contributions when it leaked out that Edison was making a last search for a better raw material.

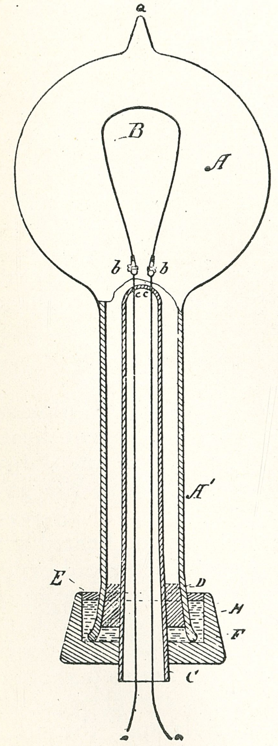
It would be tedious to name the different kinds of woods, grasses, plants, and hair, human and animal, that were tried. Yes, we even plucked the red whiskers of a Scottish guest at Menlo Park and the black ones of a Swiss and made bets on which would prove the better filament. As the thousands of samples came to Menlo Park, Edison examined each under his old verdigris-covered microscope. Those found acceptable for further trials were laid aside, while others that did not possess the qualities he desired were consigned to the stove. Carbonizing, blowing the glass parts, exhausting the air, and testing, continued day and night.

Further experiments included treating carbonized filaments in hydrocarbon liquids and vapors while a current heated them. Dr. Haid made different kinds of gases and Edison studied their effects. I remember his saying that the gases tend to destroy the filaments gradually by a sort of air-washing, for strong currents are set in motion at the heated sides of the filament. Edison also repeated some of the old experiments of 1879, impregnating raw filaments with solutions of various hydrocarbons such as rock candy, whale oil, tar, turkey red oil, cotton oil and an endless number of others.

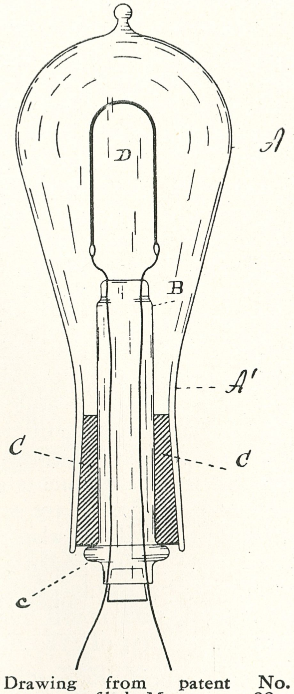
In the early part of 1880 Edison told Boehm to make some glass and rubber stopper lamps. In these the glass stopper served as the glass stem did in the other lamps: through it passed the lead wires to which the platinum clamps that held the carbon filaments were attached. These glass stop-

pers after grinding were inserted into an equally ground aperture in the lamp bulb. With the application of a little specially prepared wax they made an air-tight joint. Edison hit upon that idea while watching the Geissler-Sprengel air pumps with their ground glass connection joints. He also made lamps with stems that were forced through rubber stoppers, and they too gave quite satisfactory results.

Our narrative is still in the midst of the brilliant events that were exciting interest during the early part of 1880, when Edison, harnessed to his work, was making rapid progress in commercially perfecting his lamp.



Drawing from patent No. 239,373, filed August 7, 1880. Edison's rubber plug lamp.



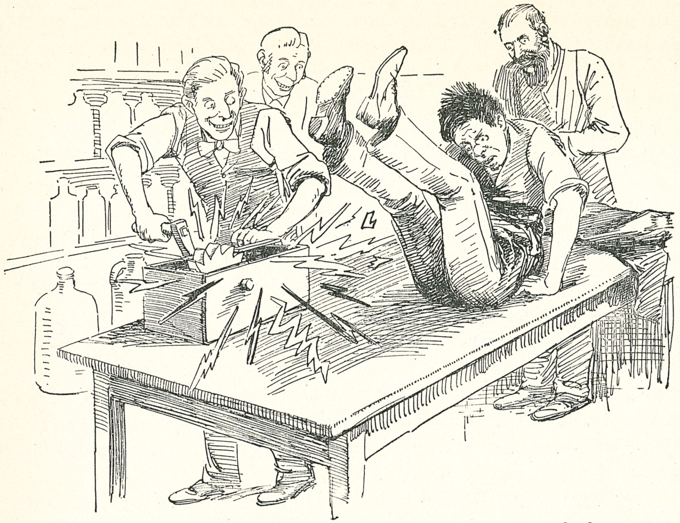
Drawing from patent No. 251,543, filed May 24, 1881. Edison's stopper lamp.

At that time Brush, Thomson, Houston and Weston were busy with their arc light system and none had faith in the little lamp that Edison had given to the world. That their disbelief was in error how well we now know! For the little lamp of high resistance that began to cast its glow in that day has kept on glowing everywhere, as does also the spirit of Edison its inventor.

Our busy activities during that development period were now and then interrupted by some merry interlude. Occasionally the 'boys' played jokes on each other. Sometimes one of them who had become tired would seek a nap on a near-by table. While no one objected to a peaceful slumber, if the delinquent began to snore or attempted to imitate the chords of rhapsodies such as we now and then hear on the radio, things happened. Somebody would crash a heavy weight on the table; that stopped the snoring. As an alternative the snorer was sometimes treated to a whiff of concentrated spirits of ammonia which, too, was effective.

I remember an incident involving one of the group whose name must go unmentioned because it occupies an elevated place in the history of electric lighting. Well, he too one night became frozen in the arms of Morpheus and began to breathe pretty loudly in his sleep. The disturbance was like intermittent approaching thunder with crashes between, ending with a periodical gulping that shook the laboratory in the silence of night. 'I'll fix him,' said one of the boys with a fiendish grin; 'I have a machine that will do the business, and you don't need to waste any more ammonia.' He went away and returned with a contraption that he had been working on the day before. It was a soap box upon which was mounted an enormous rattle that was actuated by a crankshaft turned by hand. 'Watch it work, boys,' he whispered as he placed the infernal thing near the sleeper on the table and gave it a few vigorous turns. It produced a terrific noise. The poor victim fairly bounced into the air thinking that a tornado had struck Menlo Park! The boys laughed. Some of us dubbed the machine a 'corpse reviver' and others called it the 'calmer.'

You may see the 'corpse reviver' today in the Edison laboratory at Dearborn. Even Edison when visiting his friend Henry Ford in 1929 smiled at sight of it. 'There is nothing missing here,' said he. When the 'corpse reviver' is operated before ladies that visit the laboratory, occasionally one in-



Artist's drawing showing how the 'corpse reviver' worked.

quires where such a machine could be obtained, while their husbands look sheepishly on without blinking.

Visitors were many at that period and they came from all parts of the world. Edison was often annoyed by the constant interruptions to his work when he had to do the honors by showing personages round. The callers were rated by their consequence and accordingly either Edison, Upton, Batchelor, or some one else was assigned to escort them. In mentioning these visitors I must explain that they were the extra and special ones not included in the crowds that came almost every evening to see the exhibition.

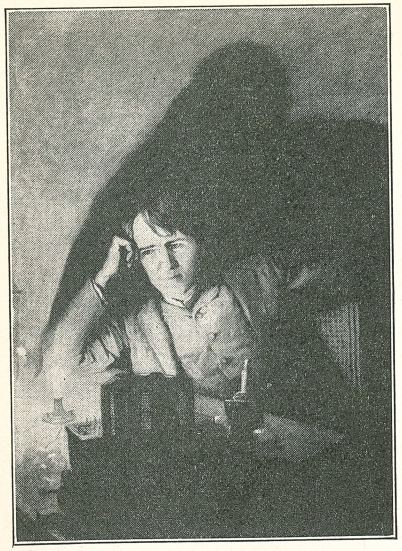
A certain distinguished electrical engineer from Cleveland, Ohio, who came to Menlo Park was taken in charge by Edison himself, who explained everything to him; the whole visit seemed one of collegiate accord. They parted like the best of friends after complimenting each other on their work. Imagine the surprise when the New York *Times* a few days later printed this gentleman's contrary opinion on Edison's light and system. I give a few extracts from that article as it appeared later in an English electrical journal.

On February 28, 1880, the *Electrician* reprinted a long article from the pen of a well-known electrician from Cleveland,

Ohio, which appeared in the New York *Times*. The electrician visited Edison's laboratory at Menlo Park, where he was accorded the attention of an honored visitor. These he repaid by indulging in some severe criticism of the inventor and his work. 'He asserts that Edison has simply resurrected a lot of scientific lumber with the design of dazzling the public. He attacks the carbon horseshoe lamp and disparages its importance. In this one point of durability which has wrecked all previous experiments during the last thirty-four years, he appears to have made no advance whatever. It has been assumed by Edison that if this lamp could be made a success by way of durability, the problem of economical electric lighting by the incandescent plan would be solved. This is far from being the case. Success would be as hopelessly far off as ever. It is doubtful if he (Edison) can get more than two, or possibly three, of these small lights per horsepower under the best management. The absurdity of the claims for the so-called Edison generator reveals the fact that it is rather a poor form of the well-known Siemens machine.

'Then he attacks Edison's modified Sprengel air pump and belittles it. Then he goes on to explain the "necessity for some automatic means of regulating the current when sudden and great changes come up, and that at present Edison has a young man stationed in the vicinity of the apparatus with his eye on the Thomson galvanometer who regulates the changes by throwing in and out resistance".' The young man that the celebrated electrician mentions towards the end of the criticism happened to be my humble self.

When Edison had finished reading the matter he said, 'What do you think of that, Batch. I explained everything to him in detail and he pretended to approve of what I did. Let me tell you this, my light and system will survive long after his is forgotten.' Only a strong, indomitable and iron-clad character like Edison's could withstand such treatment, which today only enhances the glory of his memory. Amid these seeming oddities in the human nature of others, he kept calmly on developing the filament and the process of manufacture. The hunt for the best material continued; sample after sample arrived, which Edison examined, dissected and segregated. It should be evident that with all the social conventionalities that arose during the months when his exhibition was in progress, Edison welcomed night work more than ever.



Edison watching his first successful lamp. Painting by H. M. Mott-Smith, General Electric Company's artist.

I shall here give a few other criticisms of the many that appeared at that time. United States and Canadian telegraphic and electrical notes in the *Electrician* of March 27, 1880, state:

'The repeated failures to substantiate the assertions of the practical value of Mr. Edison's labors and genius have caused a revolution in the popular feeling in regard to him, and instead of the extravagant and absurd eulogistic statements which a short time ago filled the columns of the press, disparaging and sarcastic comments occupy the columns of the newspapers generally which notice him or his work at all. It may be said that scarcely a single person at all versed in electrical science here has credited his reputed discoveries. Instead of being actuated by jealousy, as has been charged, the American electricians have on the contrary appeared very kindly and cordially disposed to "give him a fair chance." They knew that he was spending a vast amount of time and money in repeating old experiments, but hoped that he might eventually get out of the woods and really make some valuable discoveries and inventions. There has been, however, so much charlatanism and puffing in connection with his operations that intelligent people are becoming pretty thoroughly incredulous, not to say disgusted with the operations at Menlo Park. The company which furnishes the means for making these multitudinous experiments appears, notwithstanding their as yet large and profitless outlay, to have faith in ultimate success, and the experiments still go on regardless of cost.'

In the *Electrician* of April 3, 1880, is found the following: 'Edison Electric Light.—Discussion on this subject still goes on in America and the Franklin Institute has taken the matter up.' 'He gets eight lights per horsepower, but Professor Elihu Thomson pointed out that he could not get more, because the heat energy at the present given out by these eight lamps nearly equals a horsepower. He estimated the light of each at best as only ten candles, that is, eighty candles per horsepower; but with the arc method it is easy to produce 800 candles, or ten times as much light per horsepower.'

The report made on the tests of Edison's carbon filament lamps by Professor Henry Morton and Alfred M. Mayer, Ph. D., B. F., in April, 1880, after giving facts concerning the relative production of gas and electric light, concludes as follows:

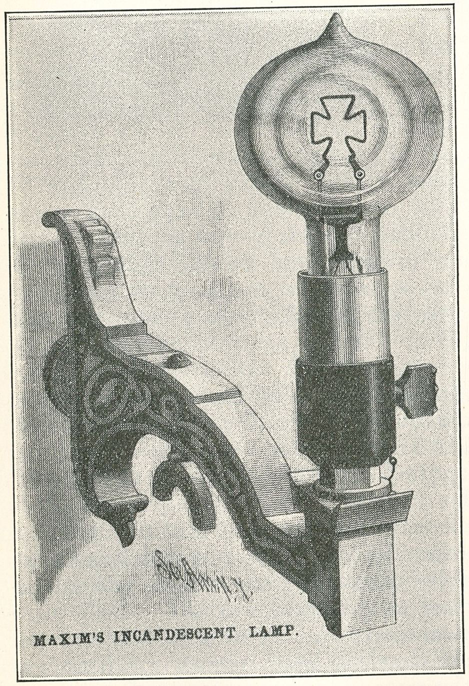
'If each apparatus and system could be worked with equal facility and economy, this would of course show something in favor of the electric light; but when in fact everything in this regard is against the electric light, which demands vastly more machinery, and that of a more delicate kind, requires more skillful management, shows more liability to disarrangement and waste, and prevents an utter lack of the storage capacity which secures such a vast efficiency, convenience, and economy in gas, then we see that this relatively trifling economy disappears or ceases to have any controlling importance in the practical relations of the subject.'

Here I mention another visitor, well known at that time, who appeared at the laboratory one day. His name was Hiram S. Maxim. He had made an arc lamp and generator which he exploited and which was known as the Maxim arc light system. He, too, as I have already mentioned, dabbled about with an incandescent lamp idea in 1878 and like others had no success. His lamp was of very low resistance and possessed many other defects—it was simply an abandoned experiment of no practical value.

Maxim was very much interested in what Edison showed him and the two spent almost a day together. Edison explained to him how the paper filaments were made and carbonized and all about the glass-blowing part. In fact, Maxim

spent nearly two hours with Edison in the glass house where Boehm, Holzer and Hipple were working. He, too, like the 'celebrated electrician of Cleveland' took leave with the most touching cordiality.

Maxim did not run to New York and give his opinion to a newspaper, but went to his laboratory and began trying to make a lamp after Edison's ideas. He had no success, however, and after a few weeks sent to Menlo Park an emissary who got in touch with Boehm. It was also said that the agent approached another of our men. The deportment of Boehm changed perceptibly and soon became suspicious. He was changing his allegiance to that of Maxim. In fact, he soon departed from Menlo Park and entered that electrician's employ. This as far as I am aware was the only defection that ever occurred at our laboratory in those early days. In a few months Boehm managed to place the Maxim laboratory in condition so that it was able to produce some incandescent lamps that had their light-giving element made of paper. While at Menlo Park Boehm had had the opportunity of watching all the various processes by which Edison made a practical lamp, and that acquired knowledge he imparted to Maxim. With the compensation he received, he was enabled to return to Germany and study. After receiving the degree of Ph. D. from the University of Freiburg in 1886, he returned to America.

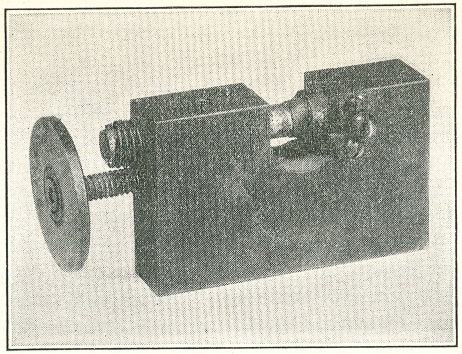


The lamp Maxim made after Edison showed his to the world

Maxim, having thus studied Edison's ideas, announced in the *Scientific American* of October 23, 1880, his new lamp, which in reality was but a bad imitation of the Edison paper lamp. Instead of making a carbon in the shape of a horseshoe, Maxim made his at first in the form of a Maltese cross and later in the form of an M. His company, the United States Electric Light Company, made several installations during its struggling existence, and then passed away, as did also Maxim the electrician—though Maxim the gun maker survived in England where he found it more congenial to live than in America. The trouble with most of the early imitators of Edison's ideas was that they had no system, while Edison had worked out a fundamental one which embraced all the necessary accessories and of which the lamp was but one of the principal parts.

In those days spies were plentiful; it appeared that there existed a regular inaugurated system of espionage for years. Later we obtained conclusive evidence of the existence of printed confidential reports from private operators—of which I hope soon to tell you more.

CHARLES A. BATCHELOR



Shaving tool with which bamboo was shaved down to a ribbon. Now in restored laboratory at Dearborn.

LXVIII. The Bamboo Filament

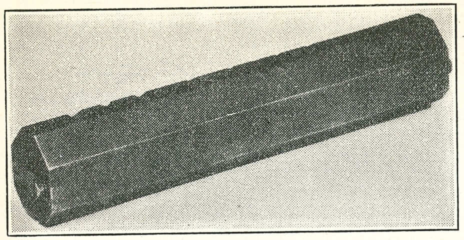
(PART ONE)

COMING back again to the laboratory, we find Edison at work, and still in the main searching for a better material, sampling samples, making experimental lamps; and so time passed on. Then one day something happened, one of those rare paradoxical incidents that often mark the advent of a new period.

As I have said, the specimen upon specimen of raw material which were examined and tried cost a great deal of time and money to procure. And where at last was the prize sample found but in our very laboratory! In our laboratory, I say, lying on the tables and exposed to view all the time it was being hunted outside. We always had, just as you will find now in the restored Edison laboratory of The Edison Institute at Dearborn, palm leaf fans lying about on the tables upstairs; these fans were often used in the course of experiments, especially when we desired to evaporate some liquid in a shallow glass plate or dry some mixture. It thus happened sometime towards the latter part of April or May that Edison noticed, while doing some microscopic work with a filament of carbon, that one of these fans was lying near his instrument.

In his stooping position he noticed that a part of the binding rim of the fan was detached and was away from the fan leaf. He received the impulse to take the fan up and examine the rim: on closer examination it was found to be made from some sort of cane. He cut a piece of it, planed it and put it under his microscope: its structural characteristics were the most ideal thus far obtained. Batchelor was called to prepare a few raw filaments from the rim of the fan and carbonize them. The results were that Edison was satisfied that he now had a better carbon than that produced from the paper cardboard. Hughes was again sent to New York to pick up all kinds of cane wood, especially the various kinds of bamboo. Bamboo brought a cessation for awhile in the hunt for raw material that would be an improvement. Lamps made with bamboo filaments were exceedingly successful from a commercial point of view as regards manufacture. Now came the question of the kind of bamboo to use; for Edison soon found that there existed an endless variety of such tropical grasses. He also surmised that one kind would no doubt be better than another, and on this point he soon convinced himself. All the varieties that could be obtained in this country were soon under microscope, knife and fire at Menlo Park, and experimental lamps were constantly being tested. Edison was also busy thinking out ways and methods of manipulating the bamboo in the production of raw filaments.

Batchelor and Kruesi were kept busy designing and making various small apparatus to cut, plane, and finish the bamboo ready for the carbonizing mould. As we know, the ultimate object in all such pioneer work is to get results irrespective of the way of obtaining them. After the main purpose of the research has been fulfilled, then the secondary purpose of improvement in the art for the sake of obtaining the desired effect can be attended to. So it was with the gigantic industry that Edison created during 1879 and 1880—not alone the lamp but everything relating to the distribution of electrical energy. Step by step improvements followed all along the line; and yet embedded in every improvement were the fundamentals that Edison expounded when he was first exploring the dark territories of a force called electricity. This way of obtaining results found favor among some really great men of those days, as can be exemplified by what the famous John Tyndall said in a lecture before the Royal Institution: 'Edison has the penetration to grasp the relationship



Finishing tool (for 8-candle power lamp) with which the thin bamboo ribbon was finished into a raw filament with shanks. (Now in restored Menlo Park laboratory.)

of facts and principles and the art to reduce them to novel and concrete combination.'

A pioneer system was gradually being evolved in the operation of handling the bamboo in all its stages, from the stem down to the finished raw filament ready to be carbonized. As we know, the paper filaments as well as the bamboo ones were cut with shanks at their extremities, an expensive process but also one that limited the production of carbons in quantities.

Yes, a new and mighty industry was in the act of creation there at Menlo Park which should later be extended to all civilized countries. Brilliant men would follow and would contribute their abilities toward developing and improving the pioneer mechanisms based on tenets that were expounded by Edison and that form the foundation of the lamp still in use.

Edison had also to work out a carbonizing mould for his bamboo filament. We few old-timers left from those days still remember the nickel ones that played such an important role in the beginning of the new industry. These were neat affairs having loose guide pieces in each end arranged so as to hold the bamboo filament in position, allowing at the same time for contraction. When put into the furnace these moulds, each holding one filament, were placed one upon the other like a pack of thick cards. The bamboo filaments having shanks at their extremities and being bent at the top were difficult to carbonize with more than one in a mould. Edison desired to have neat-looking filaments: the contrast between the earliest bamboo ones and those made later is quite marked. For some time at the beginning we were very liberal in the use of platinum wire and clamps, for the early filament was held just as the paper horseshoe one, with a

platinum clamp. Later in this same year Edison plated the shanks of the filaments with copper and thus prevented much loss in breakage while they were being placed in the clamps. Two of those lamps having only their shanks plated are preserved at the Edison laboratory in Dearborn.

A radical change soon took place; the platinum clamps were discarded and in their place was substituted a crude sort of copper clamp that was just sufficient to hold the shank of the filament. The stems with the copper clamps and filaments were then placed in a sulphate of copper bath in which the liquid only reached to the copper clamp. The filament and clamp were then plated one on to the other, and so a secure electrical contact was obtained. It was a great advancement, for it cheapened the making of a lamp in many ways, as is evident. Later on, in 1886, another improvement was effected when filaments were made without shanks, being held to the lead wires by a carbon paste.

I well remember the time when we were conducting experiments in plating. We made experimental lamps in which the shanks were plated with silver, gold, copper and various other metals and then tested to see if one or another would show any advantage or disadvantage. The tests soon convinced us that it was immaterial whether the plating was done with gold, copper, or any other metal. The all-copper plated connection lamps were already in use during the second Edison demonstration in the winter of 1880-81.

Then, of course, the experimental lamps that exhibited good qualities were subjected to rigid tests electrically. They were tested for life and endurance under varying circumstances and at a sixteen candle power voltage. As we were in the pioneer stage of the art, Edison also wanted to ascertain whether the switching on or off of the current had any effect. Thus lamps were tested by interrupting the current thousands of times; in some tests the current was reversed thousands of times. In other trials Edison sought to determine whether the positive or the negative direction of the current had any influence on the corresponding side of the filament; that is, whether there existed some action akin to what takes place in electrolysis, though perhaps of a higher order. As a matter of fact he noticed what he termed an 'electrical carrying,' in which particles of carbon tearing themselves away from the negative side of the filament went over to the positive. He found that the amount of such transposition

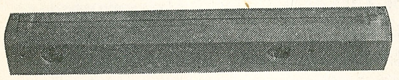
depended on the resistance of the filament, the voltage employed, the degree of incandescence and the state of vacuum.

Then there were series of experiments to overcome the blackening of the bulb and what Edison used to call 'molecular bombardment'; for he discovered that the filaments cast a shadow, leaving a line of no deposit inside the bulb. This line was in the direction of the plane of the whole filament.

Countless were the researches into phenomena developed in the interior of an incandescent lamp when in operation. They constitute a long tale which I hope to relate in a future chapter; for in those arduous labors Edison eventually discovered the Edison Effect that today is the basis of radio.

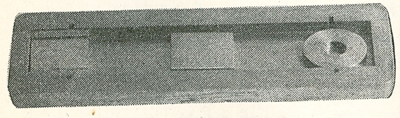
In reviewing the energy and indomitable will exercised by Edison in building up every detail of his system so perfectly, and all the operations conducted with such minute care, we can but wonder how it was possible that a single man could accomplish so much so successfully in so short a time. He had conquered both the theoretical and the practical sides of the problem, and that at a time when the science of electricity seemed wrapped in darkness.

Today we realize the grandeur and vastness of his revolutionary conceptions and we witness daily in every sphere of life the gigantic fructification of his efforts in 1879 and '80. Edison's intellectual greatness, as well as his foresight, was far in advance of that of the generality of technicians and professors. The proof of this will be found in the criticisms that abounded in those days. One college president conceded that Edison's 'system will be applicable in many of our large public buildings and hotels.' 'The step from this to the general replacement of gas is one, however, which I have not the least expectation of witnessing. The problem of carrying powerful currents of electricity for long distances, and of applying them in countless localities with economy, is one which (as I believe) calls not for ingenious inventions or combination



Above—Mould for cutting down the bamboo strip to a raw filament.

Below—Nickel carbonizing mould.

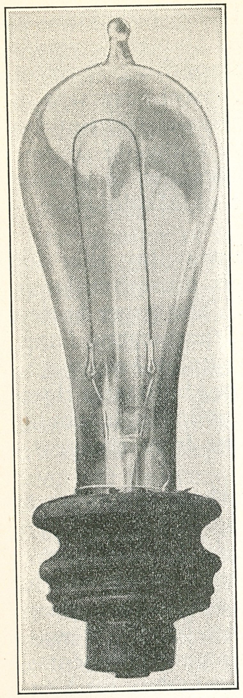


Both are in restored laboratory at Dearborn.

of known properties only, but demands new properties of matter and new laws of electric force; and though it would be as foolish as unnecessary to say that anything short of perpetual motion may not be discovered, I feel very safe in acting on the opinion that the day of universal lighting by electricity will not come in my time.' We know, of course, that new laws of electricity and new properties of matter were not necessary for the great thinker of Menlo Park—perhaps only for the purblind.

Coming back to the bamboo lamp, I may say that its filament was longer than that of the paper horseshoe lamp and consequently its bulb was longer too. The paper horseshoe lamp had a round bulb while that of the bamboo lamp was made in pear form. Edison wanted to know how much greater the cubical contents of the pear-shaped bulb were than of the round bulb. He wanted to estimate whether it would take a much longer time to exhaust the air from the pear-shaped one than from the round one.

The following incident came up during the bamboo lamp experiments. I shall describe it by quoting myself in Dyer and Martin's work on *Edison and His Life and Inventions*. 'I was once with Mr. Upton calculating some tables which he had put me on, when Mr. Edison appeared with a glass bulb having a pear-shaped appearance in his hand. It was the kind that we were going to use for our lamp experiments; and Mr. Edison asked Mr. Upton to please calculate for him its cubical contents in centimeters. Now Mr. Upton was a very able mathematician, who after he had finished his studies at Princeton went to Germany and got his final gloss under the great master Helmholtz. Whatever he did and worked on was executed in a purely mathematical manner and any wrangler at Oxford would have been delighted to see him juggle with integral and differential equations, with a dexterity that was surprising. He drew the shape of the bulb exactly on paper, and got the equation of its lines with which he was going to calculate its contents, when Mr. Edison again appeared and asked him what it was. He showed Mr. Edison the work he had already done on the subject and told him that he would very soon finish calculating it. "Why," said Edison, "I would simply take that bulb and fill it with mercury and weigh it; and from the weight of the mercury and its specific gravity, I'll get it in five minutes, and use less mental energy than is necessary in such

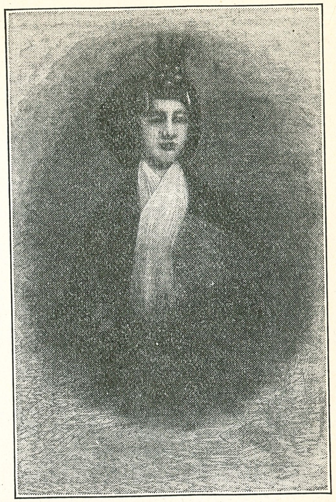


Bamboo filament lamp (16 candles) with clamps and first Edison screw base. (Now in restored Menlo Park laboratory.)

a fatiguing operation".' Cases frequently arose in which Edison explained his common-sense methods to one or another of his assistants who was bungling along on some work that he was conducting in the 'so-called scientific way.' Edison was an extremely practical and sensible worker, thinking all the time of what he was doing and accurately analyzing the results as he went along.

I have already stated that Hughes was to gather up samples of whatever varieties of bamboo could be obtained in this country. Edison, however, did not stop here, for after all the different kinds were analyzed he determined to go more fully into the matter and send a man to China and Japan in quest of the species most suitable for filaments.

Among the boys engaged at that time at the laboratory was William H. Moore. He had known Edison in 1875. He had traveled a lot and was once selling the Weston plating generators in England. While in England he had made many friends among whom were some that had visited the East on business. Moore was an energetic and likewise tactful young man with an amiable disposition; he was what we would today call 'a good pal.' It was thus no wonder that Edison selected him to go to the land of 'Dai Nippon, the Sunrise Empire.' Before he went Edison plainly outlined his plan to him and took pains to instruct him in every detail of the work he was to do. With various bamboo samples that Hughes had already obtained in New York from Japanese merchants, Edison showed him what the desirable characteristics and qualities were that he was after; he instructed him how to proceed and how to test bamboo—of which there were over two hundred species, some reaching a height of 120 feet and a



Emperor and Empress of Japan, on throne when W. H. Moore went to Japan in 1880.

diameter of one foot. Edison also sent him into the library to look up and study Japan together with everything pertaining to it. He found a lot about that country in *Harper's New Monthly Magazine*. Edison also told him to make notes regarding the samples as he acquired them in Japan, specifying their age and the environs where found. When he was ready to start Edison provided him with various utensils and apparatus, among which was a good microscope. He was given letters and credentials to our political representatives in China and Japan, in addition to which he received letters of introduction to business houses in the East from friends of his own in England. A few of us boys gave him a quiet send-off. From that day he was called 'Japanese Moore.' To travel in those days was quite a different thing from what it is today. The world was, one might say, vastly larger and distant lands were farther away. To be sent to Japan was far different and more thrilling than to be sent to Europe, as I was in 1882. Japan is the country of the great Rising Sun and has the oldest dynasty in the world. Even at that period it was considered a land of mystery and cherry blossoms. It was once a feudal empire ruled by shoguns (lords, as in

early Europe). In 1853 Commodore M. C. Perry, of the United States Navy, forced his way pompously into Yokohama and in 1854 Japan emerged from seclusion and entered the family of nations. In 1868 the Mikado was restored to full power and shogunism abolished. An era of enlightenment followed, one which has had no parallel in history. The Emperor with the aid of Prince Ito and Prince Yamagata raised an empire from ancient medievalism into the status of a first-class nation in a little more than half a century. To the above names of Ito and Yamagata we must now add those of Togo and Nogi, all of whom together with the Emperor were the pillars upon which the new and modern Japan is founded (1867-1912). A great race, wrote Moore to me once, industrious, patient, disciplined, studious, polite and yet courageous, sincere if you are sincere, honest and clever. The same testimony was given by my friend Mr. Frazar, of Tokyo.

With such people to help him Moore's search made progress, and with the further aid of his diplomatic nature his results were eminent; for he succeeded in finding a bamboo that became the standard for making the Edison filaments during ten years. Moore's resolution when he was intrusted with the job was to get results, and he attacked the problem with the energy of a go-getter; he did not take photographic apparatus or a score of lead pencils and reams of paper with him to write the tale of his adventures for the delectation of the home office *a la* Jack Harkaway. He combed parts of China but did the greater part of his work in Japan, where he visited each of the four principal islands of the empire. Soon the laboratory at Menlo Park began to receive bales of bamboo. Each sample was put through several tests including use in experimental lamps, and the results were noted. In this manner examinations went on until Moore had ended his search. He was then informed which specimen Edison considered the best and was instructed to make a contract with the grower for periodical deliveries according to certain specifications. This bamboo grew near a shinto-shrine.

After an absence of about two years Moore returned and found a job with the Edison Company for Isolated Lighting and later with the Edison Machine Works. Caught by the wanderlust, however, he soon resigned. Edison wrote him the following nice letter at the time:

Iwashimizu-Hachiman-Gu, notable Shinto-Shrine at Yawata, Kyoto Prefecture, Japan. In the grove by this shrine William H. Moore found the best bamboo for Edison's incandescent lamp in 1880.

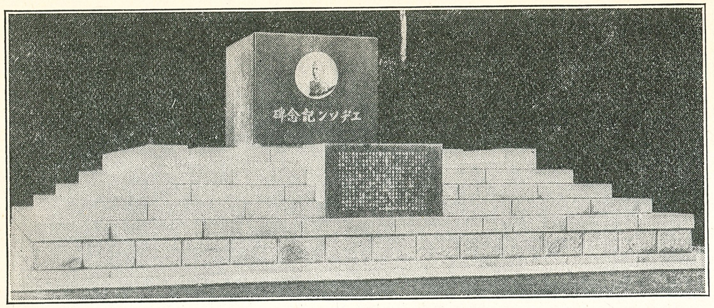
Dear Sir—I regret very much to hear that you are about to sever your connection with the Edison Company for Isolated Lighting, and it affords me very great pleasure to testify to your ability and industry in connection with the various matters that you have had in charge on my behalf.

Your trip to China and Japan on my account to hunt for bamboo or other fiber, was highly satisfactory to me, as evidenced by the fact that you found exactly what I required for use in connection with the manufacture of my lamps. I was also very much satisfied with the services you rendered me during your connection with the Edison Machine Works as purchasing agent, and have every reason to believe that you have given perfect satisfaction to the Edison Company for Isolated Lighting during your connection with them; but as to this matter I have no doubt that they will be willing to speak for themselves.

Wishing you success and again expressing my sincere regret that you are about to leave our business, I remain

Very truly yours,

Thomas A. Edison



The monument to Thomas A. Edison at Iwashimizu-Hachiman-Gu, Yawata, Kyoto Prefecture, Japan, where William H. Moore found the best bamboo for Edison's incandescent lamp in 1880.

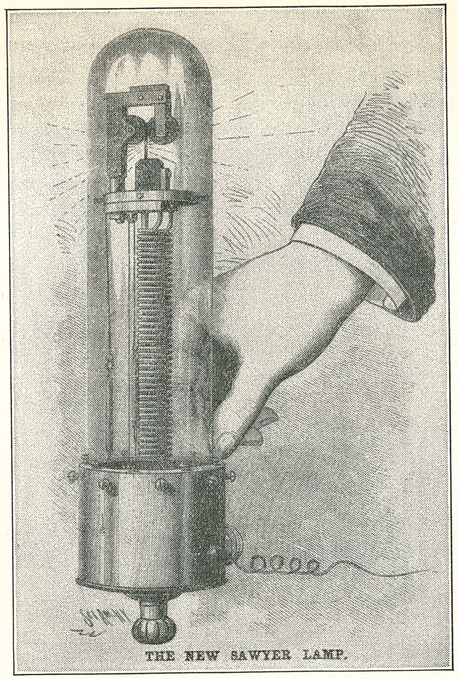
Moore's exploration of China and Japan and his success are but one of the epochal instances that abound in Edisonian tradition.

Edison did not yet, however, consider the search for the best fiber finished, for he sent P. Segedor, another of our Menlo Park boys, down to Cuba. Unfortunately Segedor was stricken with yellow fever and died. In December, 1880, a John C. Brauner, of Brooklyn, New York, was dispatched to search Brazil. Again in 1887 Frank McGowan and C. F. Harrington, who were at that time employed at the Edison headquarters at 65 Fifth Avenue, in New York City, were sent to tour South America. In 1888 a school principal, James Ricalton, of Maplewood, New York, was engaged to make a world tour. He ended the fiber hunt.

The work of all the men that followed Moore resulted in no tangible results so far as a good or better lamp filament was concerned. Though some of them left us glowing tales copiously illustrated with photographs of thrilling jungle adventures, which are out of the scope of my articles, the fact remained that Japanese Moore did the work and found in Japan the satisfactory bamboo.

* * * *

Japan has honored Edison's meritorious achievements by the erection of a monument to his memory.



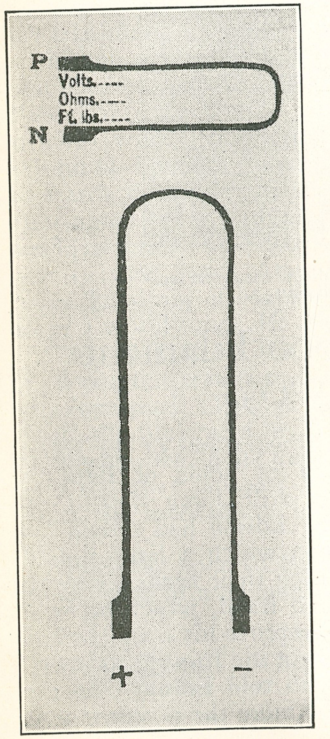
(This lamp is now in the Edison historical collection at Dearborn.)

LXIX. The Bamboo Filament
(PART TWO)

On page 476 I have given illustrations of the lamps with carbon pencils made by some of Edison's rivals. None but Sawyer still clung obstinately to that fallacious idea after Edison had shown his lamp and the proper principles upon which a lamp should be based. While others were breaking their heads trying to circumvent the Edison lamp through fraud, piracy or legal technicality, Sawyer was trying to improve his lamp, as was announced in the April 10, 1880, issue of the *Scientific American*. This same Sawyer was the man who told Edison that the higher the resistance a lamp has the more the power it will

require. That idea of high resistance and more power was entertained also by the others before Edison, for they only worked to attain a light and never contemplated what the qualities of a practical lamp should be. Any professional will see at a glance that Sawyer's new lamp had no special merit over his old one; the heat that accumulated when the lamp was in action had to be conducted away by a radiator as in his former type. Later on Sawyer seemed to understand at last how lamps should be built, for instead of continuing with a carbon pencil he went over to Edison's high resistance filament idea.

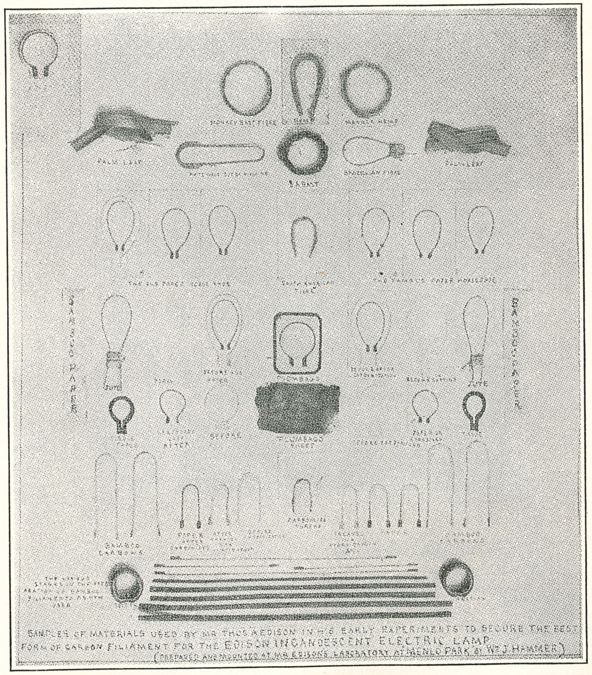
Coming back again to the work that was going on in the laboratory at this time, we find Edison still busy examining and testing vegetable fibers of all kinds. A fair estimate calculated from his notes is that no fewer than six thousand different species passed through his hands. The principal reason for seeking something better than paper was that a material had to be procured that would enable him to obtain a still higher resistance in a filament and consequently to use a higher voltage, and which at the same time would be more adaptable to transportation, that is, not so fragile as the paper lamps. In bamboo Edison found the attainment of this object for the present. And thus when the prize bamboo of Japanese Moore arrived, work on bamboo began in earnest in every direction. We had a rubber stamp made as shown at the left



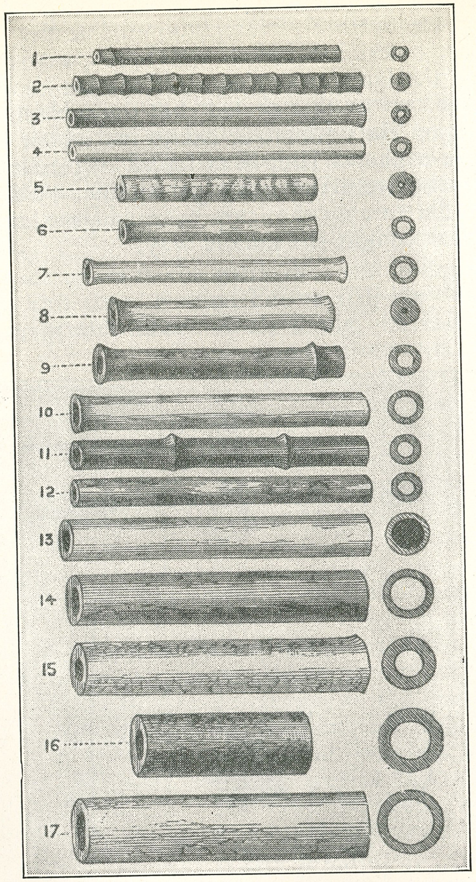
Facsimile of rubber stamp used when testing lamps. Only volts and ohms were used, since it was difficult to measure webers (amperes).—From Francis Jehl's notebook of 1881.

which recorded the volts, ohms and foot pounds on each lamp tested; life endurance tests were added to this data. Of course, the number of lamps obtainable per horsepower was readily ascertained after the foot pounds of energy required by the lamp at sixteen candles were known.

We knew even at that period that the economy of a lamp depended upon the amount of energy to which it was subjected. The higher a lamp was forced in candle power the less, we knew, were the watts per candle. We knew too, of course, that forcing the lamp up endangers its endurance, and so Edison sought the middle way.

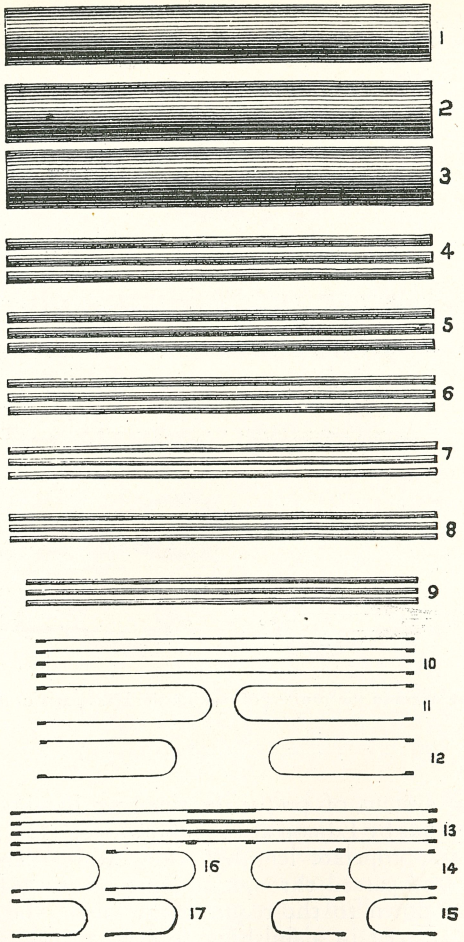


Collection of materials used by Mr. Thomas A. Edison in his early experiments to secure the best form of carbon filament for the incandescent electric lamp. Framed by W. J. Hammer.

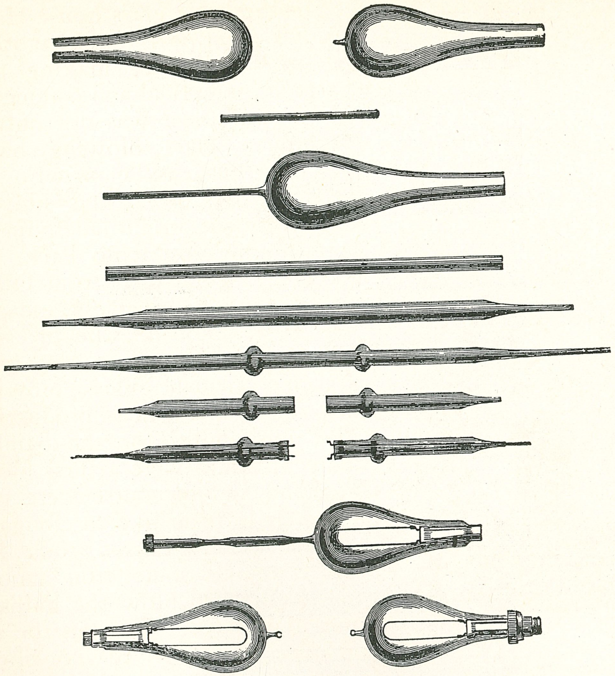


A few of the many bamboo samples that Edison tried:

1. Hauchikee	from Japan	10. Shikakuakikee	Japan
2. Nebuchitakee	" "	11. Mountain bamboo	"
3. Shihojikee	" "	12. Shikakuakikee	"
4. Sugar Cane	Venezuela	13. Brazilian	Para, Brazil
5. Horteichikee	Japan	14. Shikakuakikee	Japan
6. Kuraichikee	"	15. Yokohama	"
7. Matakee		16. Torachikee	"
8. Brazilian	Para, Brazil	17. Chinese	Hongkong
9. Hauchikee	Japan		



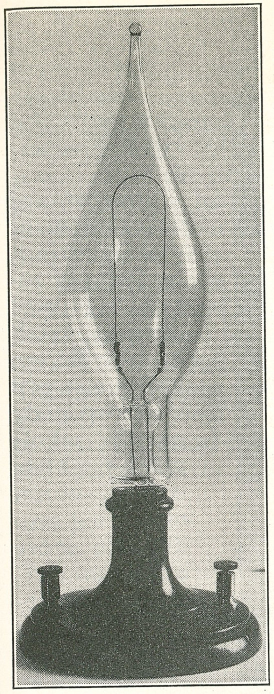
The different stages in the process of cutting and splitting the bamboo stalk down to the finishing of the raw filament ready for carbonization.



The different stages in the process of making the glass parts of the lamp.

A crude system of preparing the raw bamboo filaments was worked out by Edison at the laboratory. The sticks were sawed into appropriate lengths; these were then split into lesser sizes and passed through shaving tools. After having been shaved down to the required thickness, the ribbonlike pieces were placed in a finishing tool where the shanks and filament were cut out.

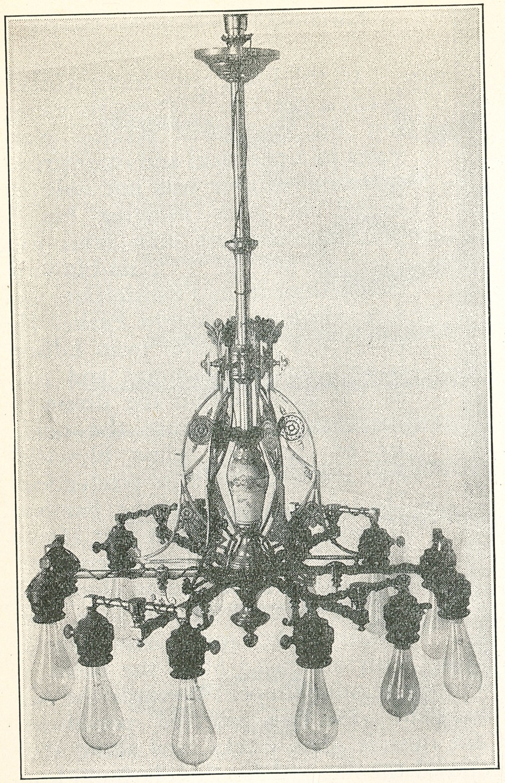
The carbonizing department had added two more muffle furnaces, so that we now had three in working order and the work there kept a few of the newly engaged boys busy day and night.



Egg-shaped bulb with bamboo filament.

In the little glass house Holzer spent a great deal of time working out the details of making glass parts in a practical and commercial manner. Holzer was not only an expert in glass blowing but a practical business man who had been owner of a glass-blowing establishment in Philadelphia before coming to Menlo Park. He received a good offer from Edison to sell out his business and join us. It gave Boehm the jitters to see Holzer degenerate the noble art of 'scientific glass blowing' into a new art of mass production. The glass bulbs for the bamboo filament lamps were at first blown by hand and of course were very irregular in form like an elongated egg or pear. Edison soon had Kruesi make some iron moulds with which to blow the bulbs in a regular shape. Towards the end of 1880 we received pot-blown bulbs from some of the outside glass works, and about this same time Holzer proposed the flat seal for the platinum lead wires. This type of seal has been employed ever since because it not only produced an infinitely better seal but saved lots of time.

For some months the platinum clamp method was still used for attaching the bamboo filament to the lead wires. This, as I may have already mentioned, was followed by copper plating of the shanks, which not only saved breakage but provided a more secure contact. Following up rapidly this idea of plating, Edison next made a copper clamp with which the shanks of the filament were copper plated together. Such complete lamps were already in use during the second and larger demonstration given by Edison during the winter of 1880-81. I may also state that at first Edison made bamboo filament lamps of 16 candle power and then of 8 candles.



This chandelier was placed in Upton's home in Menlo Park in 1880. It was the first with bamboo filament lamps. (Now in restored Menlo Park Machine Shop.)

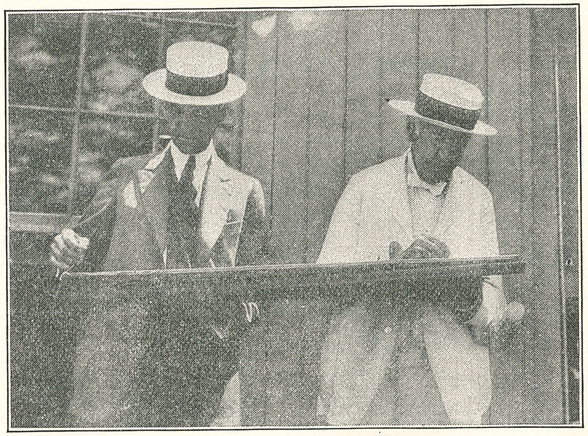
Holzer had annealers made that saved time, for formerly annealing was done by hand. In fact Edison had engaged Holzer to study out the whole glass problem with the object of making production more economical. Holzer introduced the cross-fire blowpipes with six flames at Menlo Park and being a hustler brought many practical innovations into commercial glass blowing.

Holzer took Jim Hipple and instructed him in the art. In a half year he was proficient, for he had a natural inclination for the work. Of course, after Holzer's coming an atmosphere of jealousy soon sprang up in the glass house. But Holzer was not only a good glass blower but a diplomatist, and although the air was often heavily charged it never came to a serious discharge. Thus the little glass house of Menlo Park was an historic adjunct in the part-making of many hundreds of the first efficient lamps.

Some writers have called that little shed the birthplace of the first incandescent lamps. To be exact, the first lamps were made at the laboratory complete: there the filaments

in the raw and the carbonized state were made, there they were mounted on the stem and there inclosed in the glass bulb. This happened when Boehm had his glass-blowing table on the ground floor of the laboratory, where he worked while the photograph and blueprint shed was being put into shape for him. After Boehm became established in this shed it was called the little glass house. However, no lamps, that is, no filaments, no clamps, were made and no exhausting was done there, since it was simply a place where glass was blown into shape in order to receive the proper adjuncts to a lamp.

Years later the glass shed was salvaged by the General Electric Company, who kept it at Mazda Brook Farm, near Parsippany, New Jersey. On June 22, 1929, in the presence of a distinguished group of notables, among whom were Thomas A. Edison and Henry Ford, the little glass house was officially presented to the latter. Today it is one of the many original historical relics of The Edison Institute and is in its old location in the Edison laboratory compound at Dearborn.



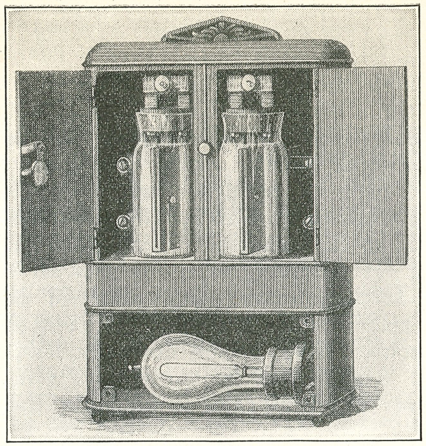
When the little glass house, now part of Menlo Park group in Greenfield Village, was taken down for removal to Dearborn, the first board was autographed by Mr. Edison and Mr. Ford.

PART FOUR

(CHAPTERS LXX TO XC INCLUSIVE)

Later Development

(FROM 1880 to 1882)



Interior of Edison 'ironclad' meter.

LXX. Edison's Electric Light Meter

(PART ONE)

WHEN we reflect with what penetrating analysis the Miracle Man of Menlo Park thought out his universal system for distributing electrical energy from house to house, we are amazed. Consider that no precedent whatever existed to guide him in his great task. As the author of the idea, he was compelled to work out the details, large and small. It was a stupendous task but he had notable resources—a healthy foresight, good common sense, patience blended with reason.

The electric light meter problem was soon solved, but it produced another important problem, leading to his invention of the 'safety wire,' or fuse, and the electromagnetic cut-out. The universal value of these two contrivances is known to all. They protect, not only the system, but also lives and property. Few of the present generation realize that the fuse plug is only one of Edison's many ingenious products.

Before I describe the research work Edison performed for the electric meter, let me remind you that outside Menlo

Park there was as yet no incandescent lighting plant. Edison alone had conceived and put into tangible form all the large and small component parts of the system, one of which was to measure the current that a customer would consume. The system had to be designed so that customers would be entirely independent of each other; that was an outstanding principle of Edison's. Scientists and laymen were equally baffled by the magnitude of his scheme; it seemed impossible simply because of its vastness. Many were puzzled because they did not yet comprehend it—it was all so novel and theoretical. Little practical application of electricity had as yet been made. Edison seemed to have commandeered the whole electrical field, which not only hurt the pride of many of the 'high-lights' of those days but actually exasperated them. For it all came so suddenly that the jolt was too much.

The laws of industrial electricity as well as the laws of the transmission of electrical energy were all contained in Edison's high resistance lamp and his constant potential low resistance armature dynamo. His system gave the world a new standard, a new conception of electricity, and helped bewildered workers in the same field to find their bearings at last.

The meter was an important item in the Edison system. The one that Edison ultimately selected was the chemical, or electrolytic, reliable, cheap to manufacture and easy to operate type. When Edison began his experiments, there was no instrument with which one could measure the current or voltage in a direct manner; all measurements had to be made indirectly. When in 1878 a newspaper reporter inquisitively asked Edison whether he could measure the electricity that a customer would consume, he replied laconically, 'It can be done.' At that time he had just conceived and worked out in his head the main adjuncts to the system which he was sure he would be able to realize. The principle upon which he had set his mind was called 'electrolysis' and was the principle upon which electroplating is based.

We are indebted to many of the great men of the past for their researches in this division of electrochemistry. Among them we may mention the names of Volta, Davy, Oersted, Wohler, Faraday, Bunsen, Becquerel, Miller, Berzelius, Berthelot. However, the true father of electrochemistry was the great Faraday, whose masterly researches, conducted about 1830, and the laws he expounded then have ever since formed the basis of the art. Michael Faraday like Edison was a self-made man and in his time the greatest experimenter in electrical science. His father was a blacksmith and young Faraday after receiving a scant education at a common day school was apprenticed to a bookseller, Riebau. First as errand boy and then as bookbinder and stationer he worked for seven years. Scientific books, lectures on natural philosophy, and then a job as a laboratory assistant to Sir Humphry Davy at the Royal Institute, furnished his early training. We all know what followed. The similarity in the careers of these two great men, Faraday and Edison, has prompted me to write this little sketch to show what an amazingly composite picture these two would make.

One of Faraday's basic laws which concerns us in the description of the Edison electrolytic meter is—in his own words: 'The chemical decomposing action of a current is constant for a constant quantity of current.'

From different experimenters we know that an ampere hour of current will deposit the following amounts of different metals:

Silver	4,025	milligrams
Copper	1,171	"
Zinc	1,213	"
Gold	2,445	"
Nickel	1,095	"

In the old days we took 1,224 milligrams as the amount deposited by an ampere hour of zinc. In fact, the textbooks gave a slight difference as regards these constants.

The equation for finding the weight of metal deposited is as follows:

$$W = qct$$

W equals the weight in grams
q " " electrochemical equivalent of the metal
t " " time in seconds
c " " current in amperes

The electrochemical equivalents of the various elements will be found in textbooks.

Edison had an inestimable respect for Faraday and the

beautiful methods of research he instituted. He said that Faraday had more than ever shown to the world that experiments are the source of knowledge. It was these methods that Edison followed all his life and through which he attained success.

Here I desire to indicate this difference between Faraday and Edison. Faraday was an expounder who interpreted the results of his researches to the public and let them take advantage of them. Edison on the other hand kept the results of his researches and experiments guarded until he had finished putting them into practical shape so that men could use them commercially. Also, Edison had obligations to fulfill, since the expense incurred in his work and the maintenance of his whole Menlo Park compound were paid for by others, who naturally expected a return on their investment.

The Menlo Park laboratory was the first commercial laboratory, providing an example that many others followed later. In those old days before 1878, the 'pure' scientists considered it beneath their dignity to 'soil' their hands in 'filthy' commercial work, although many were ready to accept the 'filthy' lucre when it was handed to them as a *donation* without obligation attached to it. Since then, times and opinions have changed, and pure scientists today march along with other workers to the factories, where they ply the same research as they once did in the universities—only their work is more thrilling, for now they sow and expect to reap.

Think of a pure scientific farmer who sows his fields and when harvest comes considers his work done and lets others reap and do anything they want with the gatherings. The scientists of today in those great commercial laboratories do far more than those of the old school; they experiment and find out data, which they themselves apply to the best advantage for men in fields of usefulness. In the old days it generally took years for scientific facts to materialize; think of the whole Edison system with lamp, generator stations, meter, all finished within a little more than a year, while others had worked on the same problem for more than half a century. Think of the automobile and the years of delay before Henry Ford commenced to make it a conveyance for all. Today progress strides along infinitely faster than in the old days.

Like Faraday, Edison was endowed with an acute perception, a mind well balanced, and fine reasoning powers. Both were natural discerners working without the use of higher mathematics; yet what they achieved was food for the mathematicians. Edison was often seen reading Faraday's great work on 'Experimental Researches in Electricity' and often he would take the three volumes home when leaving his laboratory at midnight. He would bring them back in the morning: and they were always at the laboratory and never shelved in the library. When Edison visited his old laboratory as it had been restored at Dearborn, he smiled and pointed to the Faraday volumes, saying, 'In their old place.' In fact, they were a constant source of reference to us all.(1)

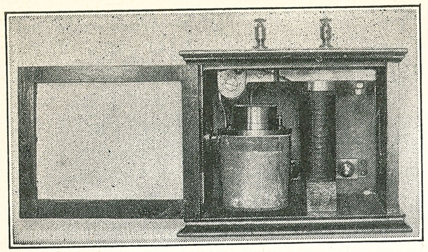
I feel that I was exceedingly fortunate in being intrusted by Edison with conducting the meter experiments at the Menlo Park laboratory and later on at the Edison Machine Works on Goerck Street in New York City. I also had the honor of taking the first commercial type meters to Europe in 1882.

I have already explained Edison's first meter experiment on pages 287, 288 and 289. He applied for a patent on the invention March 20, 1880, and it was granted on December 27, 1881, as No. 251,545. That experiment and some similar ones were conducted with copper electrodes in a solution of sulphate of copper. The beauty of the Edison electrolytic meter was that only a very small part of the current passed through the measuring cells. The resistance of the shunt was also so low that there was hardly any loss. Being an ampere hour meter, it contained no coil or anything which would consume current continuously. As the system of distribution was one of constant potential, the energy could be calculated approximately.

However, the main point to consider is that the art of generating and selling current was new. No one had imagined such a thing possible, and we can but wonder at how ingeniously Edison succeeded in matching and patching so many contrivances together into a practical system.

In the first meter with the copper electrodes he gave us the electromagnetic cut-out which (as we know) became a most useful safety adjunct in electric lighting stations. In the same

(1) A set of Faraday's works is on the table by the mechanical air pump upstairs in the restored laboratory at Dearborn.



First experimental meter made at Menlo Park. Now in restored laboratory at Dearborn.

meter he bridged a fine wire across the points of contact of the electromagnetic cut-out in order to prevent the devastating effects of the arc when the circuit was broken. Fusion of the fine wire on such occasions led Edison's active brain immediately to grasp the significance of the event. Thus the fuse plug was born, to become a household remedy. The fuse lent confidence to the Edison system when the latter was being introduced, and its safety value was enhanced by its very simplicity and cheapness. People had been timid about that uncanny force called electricity, until we stunted by short-circuiting lines or demonstrated working of the fuse; then they marveled and seemed reassured. Thus, with the start of his first meter experiments, Edison received as 'good measure' two important and universal adjuncts to his system —the electromagnetic cut-out and the fuse. The inventor himself did not at first realize the paramount importance of the fuse from a business point of view, for he did not file a patent application for it until March 10, 1880, although we were constantly using it in 1879.(2)

When Kruesi first brought over the meter with the electromagnetic cut-out and fuse and handed it to Edison, the latter examined it and then called: 'Fr-an-cis!' a way he had when in a jubilant frame of mind. 'Here is a fine job,' he continued. 'I want you to test this meter. But first look up all you can find on electrolysis and the depositing of metals. You will find a lot in Faraday; also some in Sprague and other books. When you find something you don't understand, just ask Upton if I am not around.'

Such were Edison's instructions to me at the time; and I may add that all the meter experiments conducted by me were part-time occupations, since testing was mainly done by the deposition method, which takes time in itself. Well,

(2) The patent was granted May 4, 1880. No. 227,226.

I brushed up on the subject and, after having made preliminary tests with the standard silver depositing cell, began with the meter itself. Edison had told me to begin by making a curve showing the change of resistance with the varying temperatures undergone by the cell. We knew that liquids decrease their resistance with a rise of temperature, or increase it with a fall of temperature. This action is just the converse of what happens to metals in general. Now to measure the resistances of the meter cell was not so easy as measuring wire. I had to construct another similar cell in which I could change the distance between the electrodes, after which but two tests were required to get the resistance of the cell at a certain temperature. It was mighty fine and practical work—from which my readers may infer why Wilson S. Howell once wrote me that his college was the one on top of the hill in Menlo Park.

At that period graphic methods and curves were coming into vogue and many sheets of millimeter paper were used in research work. After my having found the resistances of the cell at different temperatures, Edison told me to make a curve of the resistance changes with copper wire—an easy problem. It was these characteristics—of liquid and metal—that Edison's bright mind employed to obtain a steady resistance in the meter cell at different temperatures. The resistance of the cell plus that of the wire had to be constant, and the wire resistance we called the 'compensating' one. In order to have this compensating resistance high so that but a small fraction of the current would pass through the meter cell, the surface of the electrodes, their distance apart, and the density of the solution had to be determined.

The testing of this first meter showed, with the laboratory results obtained, that the transfer of metal from one plate to another was strictly proportional to the current, which was evident from Faraday's law. Edison, however, had some ideas that seemed to contradict the absolute certainty of the transfer of metal in the cell, as far as the meter was concerned. He explained his ideas by pointing out that in the copper sulphate cell polarization existed: the cell is always in a closed circuit—that is, when it is shunted a reverse action takes place, with a certain consequent retransfer of the metal.

He further stated that these local actions are found more or less in different solutions with different metals; yet he pointed out that the cell acts also like a Plante's element

(storage battery). The meter cell gets charged by the current from the shunt, and when the current ceases to flow, the cell discharges, since it is on a closed circuit.

Edison told me to try the experiment. I placed the meter in circuit with a standard deposition cell and sent current through it for some hours. Then I tested the plates of the standard and meter cell; they tallied. After this the plates of the meter were replaced in the cell and connected in the same manner as if it were in service, that is, closed on the shunt. Twenty-four hours later, when the plates were again weighed, we found that the standard ones had retained their weights, whereas the ones in the meter showed a perceptible difference from the first weighing. Some of the copper had redeposited itself.

Edison chuckled when I showed him the results and said that such a meter would be good for the *customer*, but hard on the *company!* He was not satisfied with using the wire on the electromagnetic cut-out as a shunt. He said that copper increases its resistance with a rise of temperature more than some other metals and that if passage of a strong current heats the windings or coils, the proportionality of the meter varies more than he wished it to.

The experience gained with this first meter was valuable and profitable; for Edison had found his 'fuse' and 'magnetic cut-out' as well as other information that led the way to better results. While talking on the copper cell meter he said: 'I'll use it in such a way that local and other actions will not count; I'll make one that will register on a counter by using the balance beam principle.'

One year later he had Bergmann build several meters, one going to the Paris Electrical Exposition of 1881. I will describe that meter later on.

After we had completed the foregoing experiments, Edison instructed Upton to learn which depositing cells were least subjected to polarization, or Plante effect, and what means could best be employed to reduce such actions. He mentioned amalgamated zincs, recalling experiences with batteries during his telegraph days. He then told us that he remembered well how the hydrogen bubbles formed a film to cause the current to grow weaker in the cell, not only increasing its internal resistance but setting up an opposing or counter electromotive force. He went on to say: 'When you shake the cell well, these bubbles escape and for a short time it is all right.'

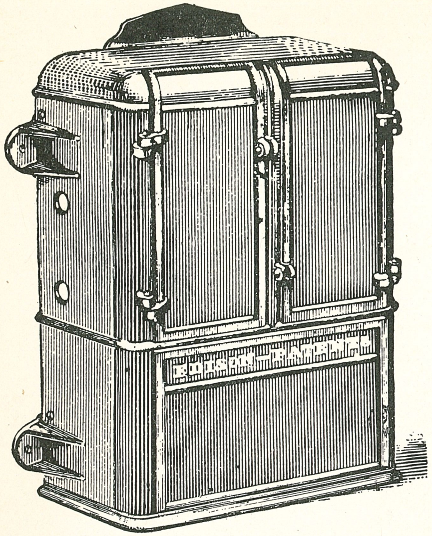
There were also chemical means that were employed, though he considered that when zincs came in question, it was best to amalgamate them.

When Upton's researches in the library led to the same conclusions, Edison decided on that metal for further experiments. Hughes, our purchasing man, had to go to New York City and hunt up chemically pure zinc, and German silver in sheet form. It was decided to use that alloy for a shunt because its resistance varied much less than that of copper with changes in temperature, though twelve or thirteen times greater than that of copper. This latter deficiency, however, was easily overcome by making its cross section larger.

My experiments with the zinc meter extended through the latter half of 1880 and up to the spring of 1881. This article would be drawn out unduly if I were to delineate all the various trials and tests made in different directions to obtain the data incorporated in the complete meter. I shall therefore confine myself to the results which led up to the time when they were given to Sigmund Bergmann to put into commercial form.

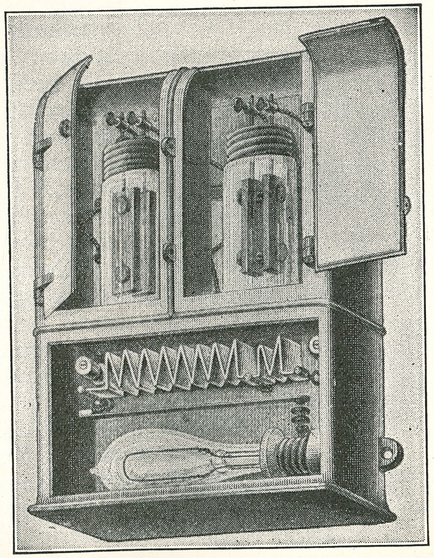
At that time Bergmann had his shop in New York City at 108-114 Wooster Street, and was getting ready to market all the various accessories necessary for the introduction of the Edison system. Since early in 1881, Edison had been away from Menlo Park most of his time. His presence was required in New York City where several establishments had been started to manufacture the parts of his system. The Bergmann shop was one place where he could be found, sometimes daily, instructing Bergmann in the various needs in accessories. He would make rough sketches and Bergmann would put them into practical form. Later, when the firm became 'Bergmann & Company,' Edison was a silent partner. It was the first firm to commence that great industry which produces electric light accessories, electric

Sigmund Bergmann, who built Edison's first commercial electric light meter at his factory at 108-114 Wooster Street, New York.



Outward appearance of Edison's first ironclad electric meter for 25 lamps.

light fixtures, chandeliers, and the like. Of the chief men who assisted Edison in the constructive work leading to productive results, Bergmann's name follows those of Batchelor, Upton, Kruesi and Clarke. Though not at Menlo Park, he was constantly employed by Edison to work out this or that for him. He possessed a wonderfully instinctive knowledge that could diagnose Edison's idea when he was handed a rough sketch with a caption: 'Put this in shape.' We must not forget that Bergmann was the commercial shaper of Edison's phonograph and chalk telephone with central exchange outfits, and the founder with Edison of the



Right—The first types of Edison meters were inclosed in an iron case.

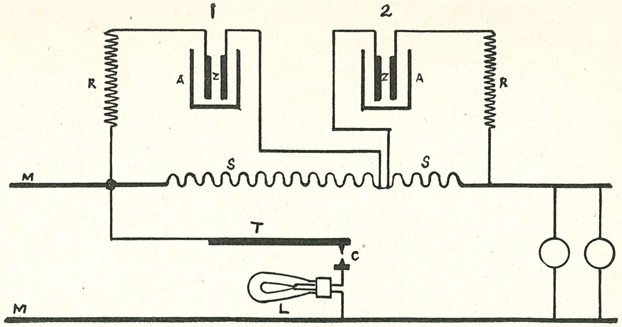
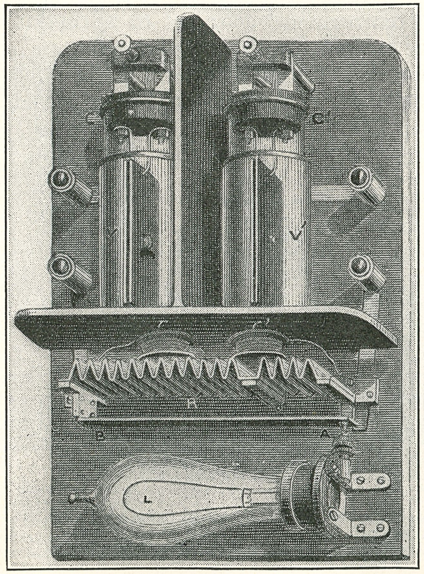


Diagram No. 1.

electric lighting accessories industry. His honorable career and the success he attained in life prove all this and more.

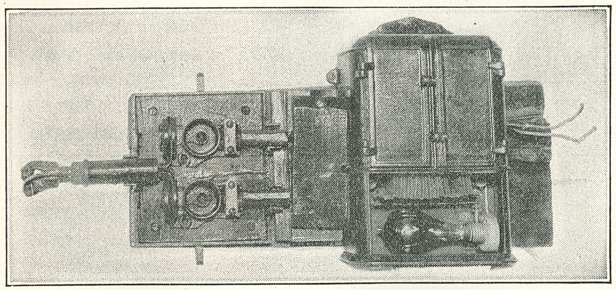
So it happened in the early part of 1881, after I had finished with what seemed to be at the time some of the most important tests pertaining to the zinc meter, that Edison went to Bergmann's shop with a rough sketch and verbal instructions—and the zinc meter began to be built gradually into serviceable shape.

Diagram No. 1 will give you the fundamental principle upon which the Edison meter was retained for many years, although its housing and various small parts were changed from time to time without affecting this basic idea.



The wooden base, showing how the meter parts were installed.

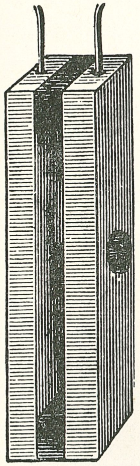
Two small glass jars, A, A (each about 4¼ inches high and 2¼ inches in diameter), contained a pair of chemically pure zinc plates Z, Z, that were thoroughly amalgamated with pure mercury. The solution in which these plates were immersed was chemically pure sulphate of zinc consisting of ninety parts of the chemical and one hundred parts of water. At 18° Centigrade it had a specific gravity of 1.33. This was the strength used at first and continued for some time. Later, when I was in Europe, changes were made from time to time in the proportion of the zinc sulphate and the water, the sulphate being considerably reduced. Each of the electrolytic cells was in circuit with a compensating resistance of copper wire R, R, and the terminals of these circuits were connected with the shunts S, S. Cell No. 1 was connected with the higher resistance shunt and No. 2 with the lower one. The resistance of one shunt was four times that of the other. As both cells, together with their compensating resistances, were equal in every respect, it was evident that cell No. 2 would have only one-fourth of the metal deposit received by No. 1. We used to call cell No. 1 the 'monthly' one, and cell No. 2 the 'quarterly,' or 'check' one. To keep the solutions in the jars from freezing, Edison inserted a thermostat T in the meter. When the temperature dropped to a certain point, it would connect a lamp L at the contact points C. Thus the radiant heat that the lamps produced raised the temperature of the air within the meter until the thermostat acted and cut out the lamp again.



One of earliest Edison meters with its main fuses, taken from a cellar where it served to meter current coming from the Pearl Street central station in New York City. (Now in the Edison historical collection at Dearborn.)

The Edison thermostat device consisted of a slender strip of brass and steel closely compounded together by rivets. This compound strip was held at one end, while the other end was free to move, and had a contact point which is shown at C. When the temperature fell, the brass contracted more than the iron or steel, and the compound strip bent and brought the contact points together, the lamp receiving the current. When the temperature rose, the strip straightened and the contact was broken. The contact points could be regulated and adjusted to act within a few degrees.

In studying the diagram, we are compelled to pay tribute again to the greatness of Edison's mind, and are enchanted with the beautiful way he solved those early problems. The entire system which he created seemed at first intricate and perplexing to the world at large—difficult to comprehend. Then by the magic impulse of his great intellect he resolved the impossible into simplicity itself. He must have a meter to measure the intangible, hardly known force that he had already harnessed; he solved his problem in practical fashion. He blended into serviceable form the laws of the great Faraday, and made them useful in one more new way. His work and methods were rational and an inspiration to all, and the results that he obtained have proved a universal blessing.



Pair of zinc electrodes used in the first commercial Edison meter of 1882.

The dimensions of the meter's zinc plates at that time were: length 3 inches, width 1 inch, thickness ¼ inch. The plates were separated from each other by a distance of 0.24 inch. Later, as practical experience was gained, changes were made to harmonize with conditions that arose in service. The zinc plates were held apart by two little ebonite blocks and an ebonite screw. The shunt was made of a band of corrugated German silver well annealed. At each end it was soldered into a clasp of copper together with a wire to which the compensating resistance was joined. The shunt for a 25-light meter had a resistance of 0.01 ohm at 85° Fahrenheit, and the shunt for the check bottle of 0.0025 ohm. The length of both shunts together was about 38½ inches, the width 2¼ inches, the thickness about 0.01

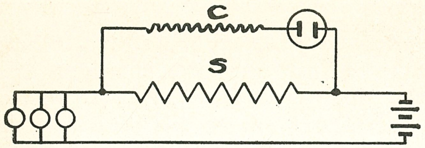


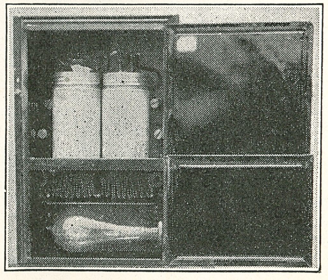
Diagram No. 2.

inch. (These were the dimensions in 1882.)

To calculate the constant of an Edison meter from the data acquired after determining the resistances of shunt, compensating coil and cell, we proceeded as follows: The first problem was that of a divided or shunt circuit. In Figure 2 we have such a circuit, with S representing the shunt and C the compensating coil and cell. The currents flowing through S and C will be inversely proportional to their resistance. Thus if S is equal to 0.01 ohm and C to 9.99 ohms, the current flowing through S will be 999 parts of the whole, while that flowing through C will be but 1/1000 part. If, therefore, a weber (ampere) hour deposits 1,213 milligrams of zinc (old constant), 1/1000 part of this would be 1.213, which figure represents the meter's constant.

Therefore, when the station's meter man weighed the zinc plate after it had been in actual service for a month or so, the weight gained (the negative plate gains while the positive loses) had to be divided by the constant 1.213 in order to arrive at the total number of weber hours consumed. The results obtained were then multiplied by the price per weber hour that the company charged. In practice, of course, the meter's constant was expressed in one figure including price, and this was then multiplied by the weight gained in the meter cell.

The meter's constant, however, was never calculated. Edison, determined to be sure, had it obtained by actual tests at different loads. From the weight gained in the cell and from the weber hours that passed through, the actual constant was determined. Before ampere-meter-measuring instruments came, I always determined the current through the means of silver



Later types of meters were housed in sheet iron cases. This instrument may be seen at the Edison laboratory in restored Menlo Park.

and copper standard deposition cells, using one to check the other. Even when Edison called me away from Menlo Park in the latter part of 1881 to install and take charge of the testing room at his Goerck Street Machine Works, I directed the further meter work, for there were always certain little changes to be made. I continued with these researches until I was sent to Europe in February, 1882, with the first commercially made type.

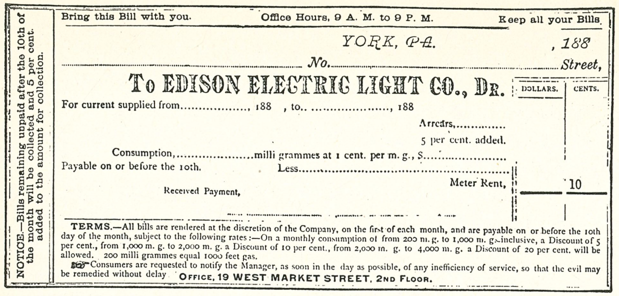
After my time Edison continued to improve the meter in many details, as practice demanded. When I left America, we were making two types, one for twenty-five and another for fifty lamps in the two-wire system. Later, Edison proportioned the shunt and cell circuit with its compensating resistance so that one milligram was deposited in the cell for meter type No. 1. In type No. 2 two ampere hours were required to transfer one milligram, in the No. 4 type four ampere hours, and so on.

Interesting are the following tables and the data they furnish concerning the Edison electrolytic meters that served in commercial work for more than ten years:

Meter size and number	Ampere hrs. per milligram of deposit	Ampere capacity of one shunt	Resistance of one shunt in ohms	Fall of potential in shunt at full load in volts	Resistance of compensating spool at 70° F.	Total capacity of meter in ½ ampere lamps	Resistance of cell at 70° F. in ohms	
1	1	10	0.04	0.4	46.46	20	2.5	Meters
2	2	20	0.02	0.4	46.46	40	2.5	for the
4	4	40	0.01	0.4	46.46	80	2.5	two-wire
8	8	80	0.005	0.4	46.46	160	2.5	system.
1	1	10	0.04	0.4	46.46	40	2.5	Meters
2	2	20	0.02	0.4	46.46	80	2.5	for the
4	4	40	0.01	0.4	46.46	160	2.5	three-wire
8	8	80	0.005	0.4	46.46	320	2.5	system.

From these we see that the three-wire system meter was simply a double two-wire one. In course of time the shape of the cell jars or bottles was changed a little, as were also the dimensions of the zinc plates; the quarterly shunt was discarded. One shunt served both cells in a two-wire meter; and the two shunts in a three-wire meter each served their two jars.

SOME EARLY ELECTRIC LIGHT BILLS



NOTICE.—Bills remaining unpaid after the 10th of the month will be collected and 5 per cent. added to the amount for collection.

Bring this Bill with you. Office Hours, 9 A. M. to 9 P. M. Keep all your Bills.

YORK, PA. , 188

No. Street,

To EDISON ELECTRIC LIGHT CO., Dr. DOLLARS. CENTS.

For current supplied from ...., 188 , to.. ...., 188

Arrears,.............

5 per cent. added.

Consumption,....................milli grammes at 1 cent. per m. g., $........................

Payable on or before the 10th. Less...

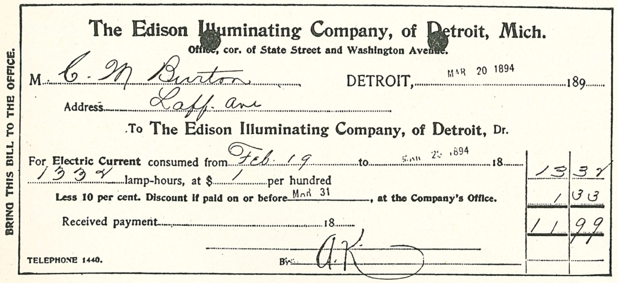
Meter Rent, 10

Received Payment,

TERMS.—All bills are rendered at the discretion of the Company, on the first of each month, and are payable on or before the 10th day of the month, subject to the following rates:—On a monthly consumption of from 200 m. g. to 1,000 m. g. inclusive, a Discount of 5 per cent., from 1,000 m. g. to 2,000 m. g. a Discount of 10 per cent., from 2,000 m. g. to 4,000 m. g. a Discount of 20 per cent. will be allowed. 200 milli grammes equal 1000 feet gas.

☞ Consumers are requested to notify the Manager, as soon in the day as possible, of any inefficiency of service, so that the evil may be remedied without delay. OFFICE, 19 WEST MARKET STREET, 2ND FLOOR.

Above—Blank meter bill from the days when that intangible force —electricity—was sold by weight.



BRING THIS BILL TO THE OFFICE.

The Edison Illuminating Company, of Detroit, Mich.
Office, cor. of State Street and Washington Avenue.

M. C. M. Burton DETROIT, MAR 20 1894 189

Address Laff. ave

To The Edison Illuminating Company, of Detroit, Dr.

For Electric Current consumed from Feb. 19 to MAR 20 1894 18 13 32

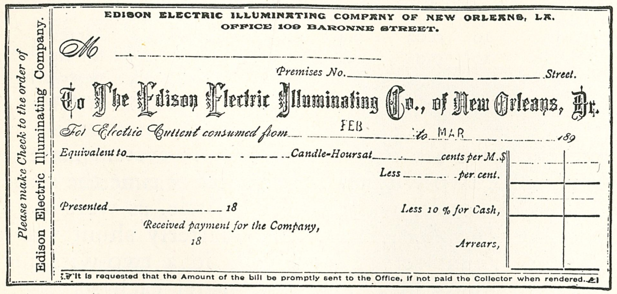
1332 lamp-hours, at $ 1 per hundred

Less 10 per cent. Discount if paid on or before MAR 31, at the Company's Office. 1 33

Received payment 18 11 99

TELEPHONE 1440. By A.K.

Above—This bill reveals how current was sold also in lamp hours. (From C. M. Burton Collection, Detroit Public Library.)



Please make Check to the order of Edison Electric Illuminating Company.

EDISON ELECTRIC ILLUMINATING COMPANY OF NEW ORLEANS, LA.
OFFICE 109 BARONNE STREET.

M

Premises No. Street.

To The Edison Electric Illuminating Co., of New Orleans, Dr.

For Electric Current consumed from FEB to MAR 189

Equivalent to Candle-Hours at cents per M. $

Less per cent.

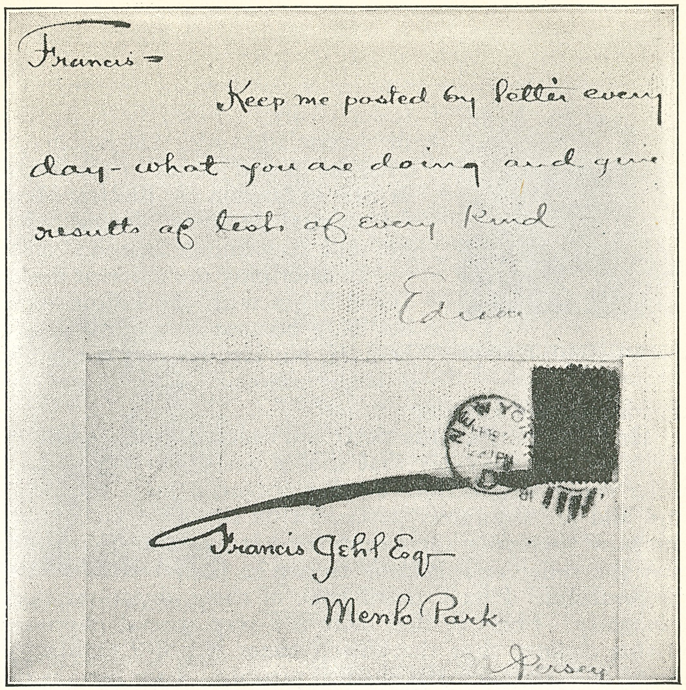
Presented 18 Less 10 % for Cash,

Received payment for the Company,

18 Arrears,

☞ It is requested that the Amount of the bill be promptly sent to the Office, if not paid the Collector when rendered.

The above bill shows how current was also sold in terms of candle hours.

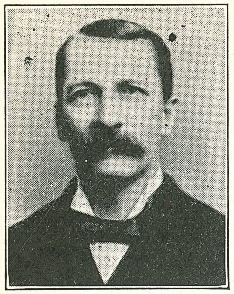


Note of instruction to Jehl from Mr. Edison. (Original now in Edison historical collection.)

LXXI. Edison's Electric Light Meter

(PART TWO)

THE fundamental elements of Edison's electrolytic zinc meter, as worked out at Menlo Park, were always retained. It played an important part in the introduction of his system. It was the best meter for direct-current until the perfected motor meter had passed through its pioneer stage; in other words, until about the middle of the nineties. A celebrated English scientist and electric light engineer



PROF. GEORGE FORBES

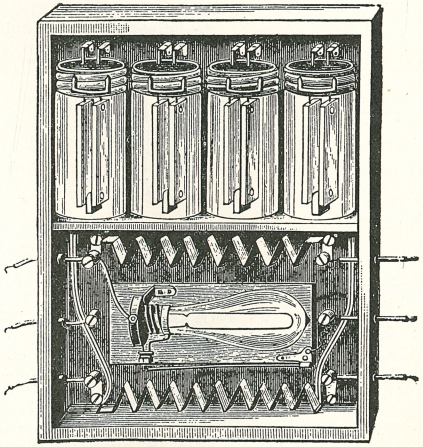
in 1889 made a thorough study of meters, in both America and Europe. Old-timers will recall the part Professor George Forbes, F. R. S., took in electric lighting. On January 23, 1889, he gave a lecture at the Society of Arts in London on 'Electric Meters for Central Stations' during which he said concerning Edison's meter:

'In describing the different meters, I will begin with the Edison meter, not only because it was the first to be used, but also because it has done a larger amount of useful work in central stations than any other. . . .'

He then described the meter and ended his talk as follows:

'Now, you may say that this is not exactly the kind of meter we require, because customers cannot check the weighings and are absolutely dependent on the good faith of the company supplying the electricity. It has also been argued that the shunt arrangement cannot be perfect with varying temperatures. I have heard both of these objections raised frequently. I believe that there is a very general impression in this country that the Edison meter is not a satisfactory meter, and is not actually used in practice. I am certain that there is a belief among a great number that in stations in America where the Edison meter is used, they never weigh at all, they simply guess at the bills and put them down.

'This is a total error; the instrument has been used in a very large number of central stations indeed.



Later type of Edison electrolytic meter used with the three-wire system. (Now in the Edison historical collection at Dearborn.)

I agree entirely with every word in the very modest opinion which Mr. Edison expressed to me about it. He said: "It is not an ideal meter, but it is simple and effective, and gives general satisfaction wherever it is used." I endorse this opinion (applause). But the managers of central stations where it is used have given me higher estimates still of its value. They say that customers are all quite content with the manner of reading it. As to accuracy, many customers have kept accurate tally of the lamp hours which they have consumed, and compared it with the charges by meter, and have often come within 2 or 3 per cent.

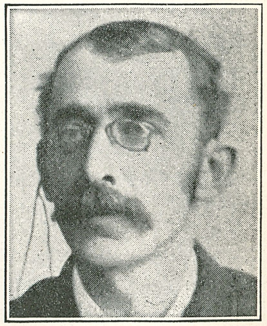
DR. J. HOPKINSON

Expert for the English Edison Electric Light Company in London in 1882.

'At the splendid central station at Milan, which I lately visited, this meter is in constant use, and is much appreciated by the company. They say that the expenses of maintaining the meter department are not large when the whole thing is well organized. The total number of ampere hours sent out from the station, as measured by the ampere meters, agrees with the meter accounts within 3 per cent.'

High praise for the first electric light meter placed in commercial service!

As I have already stated, I carried the first models to Europe with me and demonstrated them to the English Edison Electric Light Company at 57 Holborn Viaduct, London. This company had engaged the services of two scientists, Dr. J. A. Fleming and Dr. J. Hopkinson, whose labors in the early history of electric lighting are well known. To them I explained and demonstrated the Edison meter. I made several tests with them, and their report later on was favorable. The English Edison Company requested me to

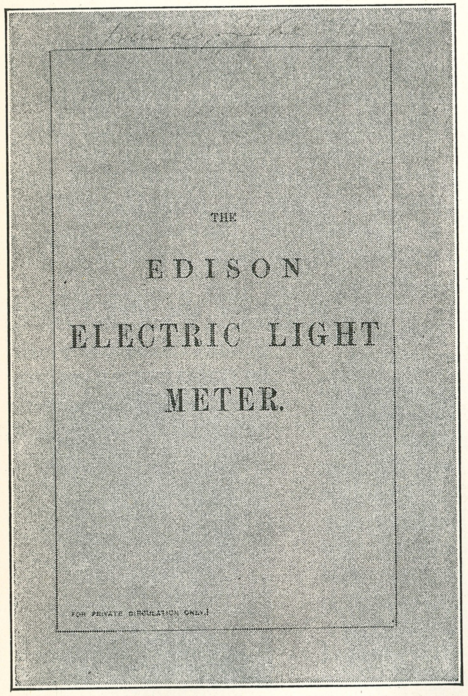


DR. J. A. FLEMING

Expert for the English Edison Electric Light Company in London in 1882.

write a description of the meter; this they printed in a twenty-four page pamphlet in March, 1882. The little treatise, the first complete account ever written of the meter, was reviewed in a four-column article in the London *Electrician* of June 3, 1882. It included three illustrations; one showing how the meter was disposed, another how we determined the meter shunts by the drop of potential method with a low resistance Thomson reflecting galvanometer, and the third how the compensating resistances were determined in a closed chamber with a thermometer by the aid of a Wheatstone bridge and a Thomson reflecting galvanometer.(4)

Professor R. E. Day, lecturer in physics at Kings College, London, demonstrated and lectured on the Edison meter (which I supplied) to a crowded and interested assembly in the college auditorium. I afterward brought the meter before the Compagnie Continentale Edison de Paris, and from there went to Milan, Italy, and demonstrated it to Professor Giuseppe Colombo, of the Royal Polytechnic College, who founded and organized La Societa General Italiana di Electricita, Sistema Edison.


THE

EDISON

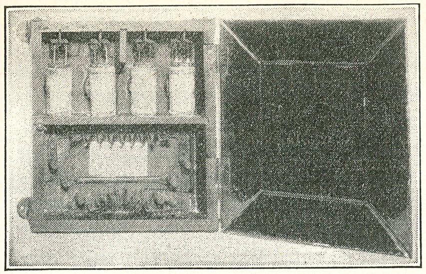
ELECTRIC LIGHT

METER.

[FOR PRIVATE CIRCULATION ONLY.]

Facsimile of front cover of Jehl's treatise. (Now at restored laboratory in Dearborn.)

(1) The Bulletins of the New York Edison Company of 1882 mention the publication of this treatise.



This meter was still in service in New York City in 1894. Note that lamp and thermostat were not in use. In localities where there was no danger of freezing, meters without lamps or thermostats were employed.

The rates and units employed by electric light companies differed in practice. We must not forget the fierce competition that raged at that period between the gas and the electric light companies. The gas companies were already deeply rooted and had enjoyed for years a monopoly that had never been challenged since the beginning of their industry. They had not shown themselves progressive, and the main use of their product was still illumination. They employed those common fish-tail burners which you will see today in our restored laboratory here at Dearborn. The Welsbach-Auer mantle had not yet been invented: today we marvel that people could see at all with the old kind of gas illumination. Gas had a high specific gravity (about 0.76), and the flat-flame or fish-tail burners consumed about five feet per hour and were rated at about sixteen candles at their flat side. That was why Edison when he first began to make his lamps sought to give them the same candle power as the gas jets. Gas sold at about $2.25 per thousand cubic feet; and a gas jet cost about 1.125 cents per jet hour.

In 1882 a weber-hour was often designated as the equivalent of 20.48 standard candles; that is, a current of one ampere for an hour would produce that number of candles of illumination. This manner of expression, of course, changed as the economy of the lamp was increased and improved. Companies had different ways of billing the consumption of current to their customers. Some used the term milligrammes, some lamp hours, some candle hours and some weber hours.

It seems paradoxical that a force like electricity which has no weight should have been sold *by weight!*

All these unit terms were of course calculated from the gain that the plates in the Edison meter showed, and those companies that employed the milligramme unit chose, no doubt, the most exact one.

The Edison electrolytic meter was used, of course, not only for lighting but also for motors. A price was made for motor service at so much per horsepower hour. The bills were made out by multiplying the ampere hours by the voltage, and the product was divided by 746, which figure represented the watts per horsepower. In regular business, bill constants were used to avoid the troublesome multiplications and divisions in each bill. Interesting are the facsimiles that we show of bills in those early days; one dated 1894 shows that even at that late period the Edison meter was still in active use.

Many persons, even as today, were suspicious of a meter, whether for gas, water, or electric service. In order to push the business and secure new customers, the companies in those early days also made contract agreements; that is, for a fixed monthly sum one could use so many lamps of a certain candle power for a certain time daily. Well we know that the most honest business methods abide by measure, and it was soon found that the contract system was not ideal. It was a sacrifice necessary in pioneering. The contract system, however, was in force only among a few—let us say, those die-hards that always 'pop up' and wish to secure special advantages. Gradually the public saw the advantage of the meter system over that of the contract; after expending its lust for blazing every lamp, sometimes longer than the allotted time, it soon realized that it could even save money by having the current metered.

As I have already mentioned, the Edison chemical meter remained basically the same throughout the many years it was used in practical service; it performed valuable services in the introduction of a new system, all of which amazed and thrilled a world full of future possibilities. Here, too, I wish to pay tribute to all those companies and men who, when the meter was put into service, made valuable suggestions as practice dictated, and helped in its successful introduction. All aided the pushing of the great pioneer elements of a great system forward—one which today has been extended to all parts of the world. No matter under what name or flag, wherever the universal system of electrical energy transportation for light, heat, and power is known, it is The Edison *System*, basically.

Edison made another interesting meter of the electrolytic type. It was never put into commercial service, although it

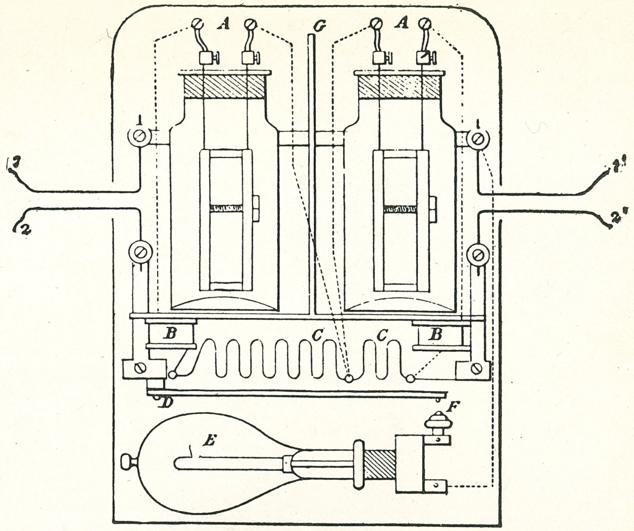
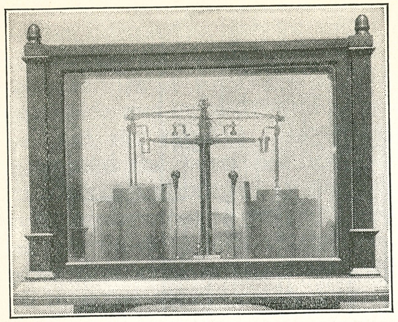
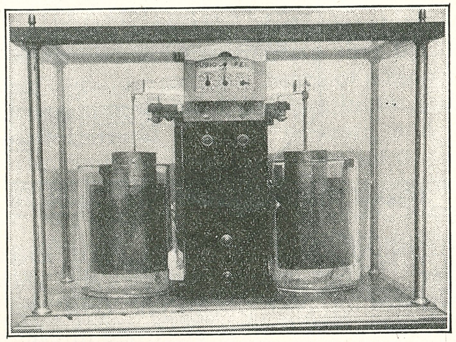


Diagram from Jehl's treatise (1882) showing disposition of the meter.

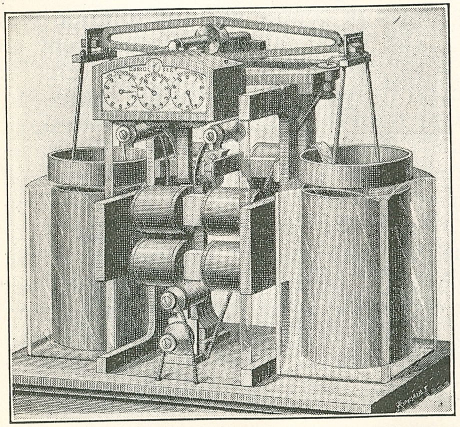
astonished everyone at the Paris Electrical Exposition of 1881. The meters, which are shown on page 660, consisted of two electrolytic cells, each having a pair of electrodes. The outer electrode in each cell was fixed while the ones in the center were suspended at the end of a balance beam. The electrodes were of copper and the solution was sulphate of copper. The electrical connections were so arranged that when a current passed through the cells, it caused a transfer of metal to one of the suspended electrodes, while taking metal away from the other. This action caused the beam to be gradually depressed on one side. The beam had a sort of pointer attached to its center that tilted a pivoted V-shaped contact piece at a certain point during the depression of the beam on one side or the other. The contact piece threw in an electromagnet that reversed the current in the electrolytic cells. When the direction of the current was reversed, the opposite end of the beam began to descend and eventually caused the pointer to set the electromagnet into action again and thus to reverse the current. In this manner the beam would slowly seesaw, each oscillation registered by a counter.



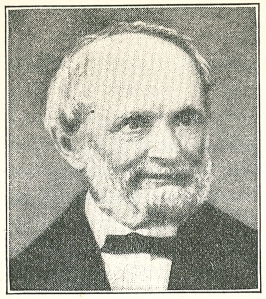
Apparatus used at Edison Menlo Park laboratory in electric meter experiments. Now in the Edison historical collection.



Edison balance meter. Now in the laboratory in restored Menlo Park, Dearborn.



Edison balance meter with counter. (Now in restored Menlo Park laboratory.)



WILHELM WEBER

1804-1891.

Edison in his patent No. 240,678, filed October 7, 1880, called the meter a webermeter in honor of the eminent German physicist Wilhelm Weber. In our days at the Menlo Park laboratory the unit of current was called the weber. When the Paris Electrical Congress met in 1881 it was changed to 'ampere' in honor of that celebrated French physicist Andre Marie Ampere. Thus the three great industrial units of electricity bear the names of men from three nations: Volta of Italy, Ohm of Germany and Ampere of France. (2)

The Edison balance electrolytic meter with counter had, like the commercial chemical meter, a shunt and compensating coils, and it operated well at the laboratory. There were other experiments on electrolytic meters of different types that Edison trusted me to conduct, meters based upon various physical laws. As they were never reduced to practical work, I shall only dwell upon one of them.

This one has historical value, for it pertains to the first motor meter ever made. Edison applied for a patent on it February 24, 1881; this was granted June 14, 1881, as No. 242,901.

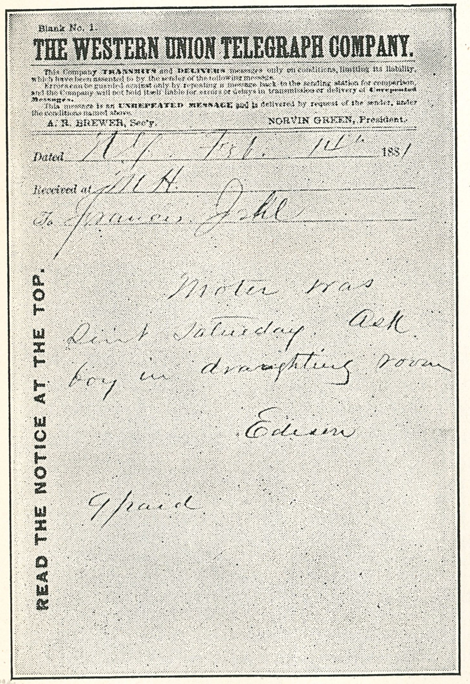
I began these motor meter experiments in the early part of February, 1881, at a time when Edison was traveling constantly between Menlo Park and New York City. Most of the 'boys' at the laboratory and other departments had already been transferred to New York City, to the Lamp Works, or elsewhere, as Edison was commencing to introduce his system in a commercial way. At the laboratory there remained, besides myself, Edward G. Acheson, Dr. Edward L. Nichols and young Herrick.

From the notes of my 1881 diary I find that it was on a Sunday morning, February 6, 1881, that I arrived at the laboratory and found Edison waiting for me. He told me that he was having a tiny dynamo machine, or motor, made,

(2) Alessandro Volta 1745-1827, Como, Italy.
Georg Simon Ohm 1787-1854, Erlangen, Germany.
Andre Marie Ampere 1775-1836, Polemieux, France.

which he wanted me to try out in a meter. He then explained to me that as the current was increased or diminished, the little motor would run faster or slower and the speed would be a criterion of the current consumption. The revolutions could be registered by a counter, just like those employed by the gas companies. Of course, he added, the little motor would have to do some work in a suitable way. 'You know, Francis,' he said, 'we could use such a brake as we have on the electric locomotive (which we used to call a Funcault brake), or we might use vanes like those in clockwork, or perhaps a little dynamo.'

He then told me to try out the meter when it came, by having the armatures in parallel with the field magnets, as well as having them in series; also to test the motor meter by saturating the field, and then again with the least amount of magnetism in the field magnet at least load. He continued that Bergmann was making the meter and it would be sent to me when finished.


Blank No. 1.

THE WESTERN UNION TELEGRAPH COMPANY.

This Company TRANSMITS and DELIVERS messages only on conditions, limiting its liability, which have been assented to by the sender of the following message. Errors can be guarded against only by repeating a message back to the sending station for comparison, and the Company will not hold itself liable for errors or delays in transmission or delivery of Unrepeated Messages. This message is an UNREPEATED MESSAGE and is delivered by request of the sender, under the conditions named above.

A. R. BREWER, Sec'y. NORVIN GREEN, President.

Dated N.Y. Feb. 14th 1881

Received at M.P.

To Francis Jehl

Motor was sent Saturday. Ask boy in draughting room

Edison

9 paid

READ THE NOTICE AT THE TOP.

Telegram from Edison to Francis Jehl regarding motor. (In Edison historical collection.)

At that time I was still making experiments with the electrolytic meter and various other tests which Edison required and which I shall relate in a later chapter.

It was on February 14, 1881, that I received the Bergmann meter, and at the same time a telegram

from Edison informing me that the motor was already on its way to me. Edison and I always referred to this motor meter as the Bergmann meter, because it was made in Bergmann's shop.

Having examined the meter and found that it would not work, I rewound the armature with finer wire. My diary indicates that the workmanship of the meter was 'a rough piece of business.' It was finished in the manner of a stock ticker or telegraph instrument which, for the power at its disposal, was crude. In fact it was not till some years later, after Professor Elihu Thomson had brought out his meter, that instrument makers became precision-conscious. Old-timers will remember the first motor meters with their heavy spindles, heavy copper disk and rough bearings. This was before Thomas Duncan contributed the light-load compensating coil and aluminum disk; it was before jewel bearings were used. Meter manufacture had to go through a refined process of evolution until the builders acquired that super-delicateness necessary in electric meters. At that period (1881), I, too, was already conscious that an instrument for registering current had to be made with more precision than a stock ticker, and that accounts for the entry in my diary.

I may mention that Edison had Bergmann make four vanes that acted as the retarding force in the meter. When the armature and field were connected in parallel, they gave a resistance of about 0.44 ohms. The vanes, through the means of spindles and gear wheels, made seven revolutions to one of the armature. The meter was also connected with a counter. After trials and experiments, fair results were obtained and the entry in my diary for February 21, 1881, reads as follows:

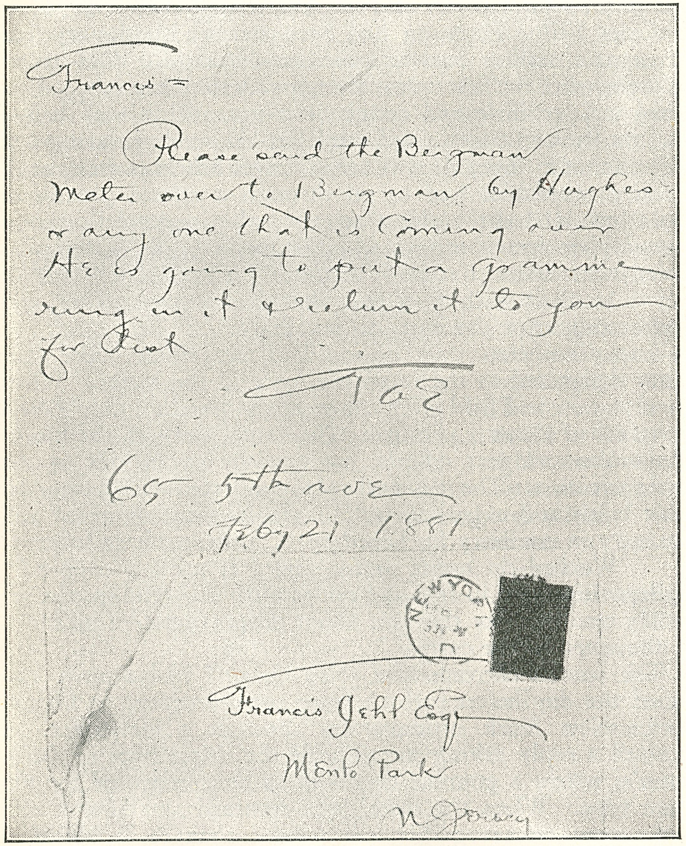
'Worked on meter motor—tried it with a copper deposition cell in line and ran it with different speeds. My results show they are about proportional—I mean the speed to the current.'

The results corresponded with those I had already obtained the day before, which were communicated to Edison at his New York headquarters through a messenger. I received a reply asking me to send the meter over to Bergmann's, where a gramme ring was to be substituted for the drum type. When the meter was returned and after I had made some tests together with some changes, I obtained about the same results as with the drum armature. The drum armature was then replaced and Edison had the meter

housed in a brass casing. He said he would have another made in which he would have only one spindle instead of four, as in the meter on which I had worked.

'It's no use having so many shafts that are a constant source of varying friction,' Edison said.

I was requested to send the motor meter over to the New York office at 65 Fifth Avenue, where Sam D. Mott, our patent draftsman, was to make a drawing for Edison's patent


Francis —

Please send the Bergmann Meter over to Bergmann by Hughes or any one that is coming over He is going to put a gramme ring in it & return it to you for test

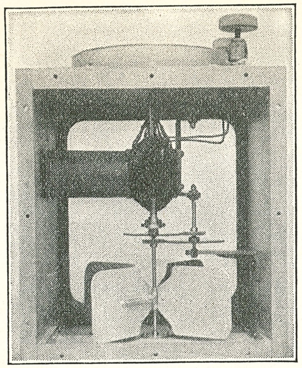
TAE

65 5th ave
Feby 21 1881

NEW YORK

Francis Jehl Esq
Menlo Park
N Jersey

Letter from Edison to Jehl about Bergmann meter. In the inventor's own handwriting. (Now in Edison historical collection.)


First electric motor meter made by Edison in 1881 and now in restored Menlo Park laboratory.

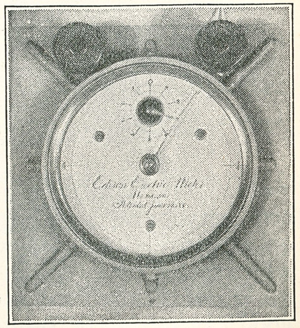
attorneys Messrs. Dyer and Wilber. That was the last I saw of the meter; until, after a lapse of more than a half century, it and I came together again at the old Menlo Park laboratory here in Dearborn. It was a relic that Edison had prized; and he kept it at Orange, New Jersey, until a few years ago, when he donated it to his friend Henry Ford.

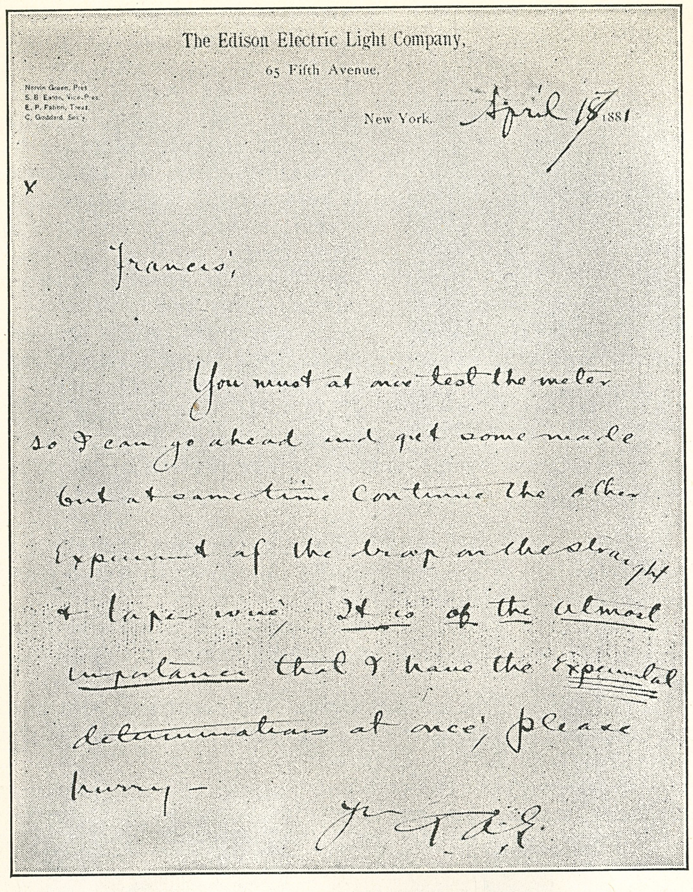
I continued work on the electrolytic meter which Edison wanted to put into commercial shape. It was nearing completion when on April 17, 1881, Edison wrote asking me to test it. The portion of the letter referring to the drop on the wire will be explained in another chapter.

When I pause and squint at the meter now and then, it seems to say 'Do you remember the time long, long ago when you used to fuss with me so much?'

I murmur: 'Yes, those were the days when the great Edison was here. Though he has now left us, his spirit still lingers.'

And I add: 'You are not alone. On every side you have the other old friends that did their share to help the master when he was here. There's the old phonograph, the carbon telephone transmitter and the chalk telephone receiver; near you are many of those pioneer lamps that blazed a new trail and marked a new era in the world; with them are also the Effect Lamps that had to wait so many years before they were ushered into society, as the coming debutants, to make possible the realization of radio transmission. All these and many more of your old friends that


Dial of Edison's motor meter.



The Edison Electric Light Company,
65 Fifth Avenue,
Norvin Green, Pres't.
S. B. Eaton, Vice-Pres.
E. P. Fabbri, Treas.
C. Goddard, Sec'y.
New York. April 18/1881

x

Francis;

You must at once test the meter so I can go ahead and get some made but at same time continue the other Experiment of the heap on the strap & paper wire; It is of the utmost importance that I have the Experimental determinations at once; please hurry —

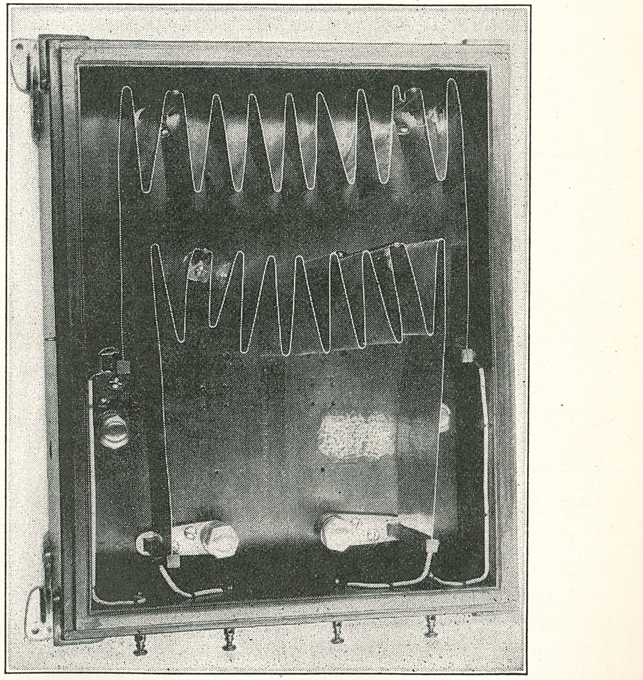
Yrs T. A. E.

Letter to Jehl from Mr. Edison in the inventor's own handwriting. (Now in Edison historical collection.)

made their way as leaders in the path of progress are assembled here again never to be separated. You will all remain in the old laboratory and each will bear witness of the great Edison who created you. He is not here, but has intrusted you to his friend Henry Ford as your guardian; you will be taken good care of in the future. Although you speak not man's language, your very appearance and actions say more than

words. Yes, it is good to have the whole family back home to stay.'

Edison took out twenty-two United States patents on meters, some of them very interesting. I shall mention one more, since it, too, like the motor meter, is of historical significance. I refer to Patent No. 370,123, the specification for which was signed on April 6, 1883. This, the first of its kind, was called by Edison a 'mono-electrodynamic motor.' Later it was called the 'mercury-motor' type. The mercury meter operated according to the laws of electrodynamics, and the many beautiful experiments that were made by Ampere, Faraday, Sturgeon, Barlow, and others form its basis.



Metering was also done by placing the cells in another locality. The resistances of the leads from the shunts to the cells were of course included in that of the compensating spool.

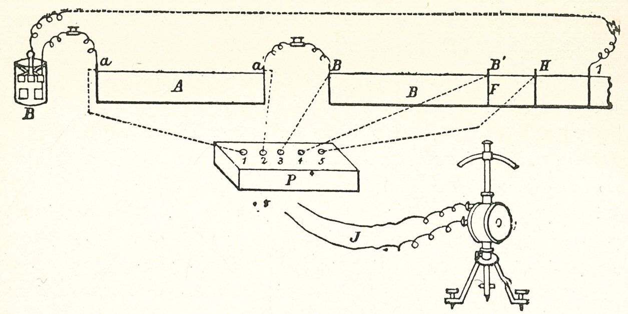
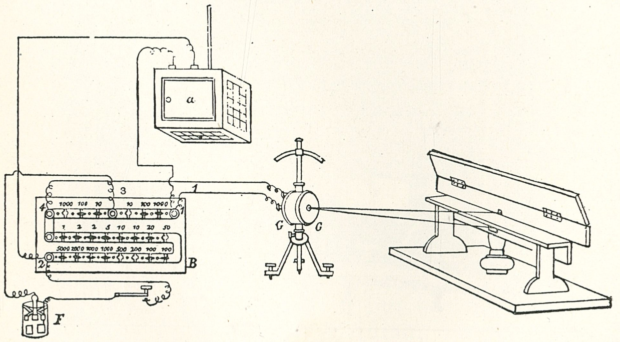


Diagram from Jehl's treatise showing method of making meter shunts.

The striking phenomenon these ancient experiments produced was that continuous rotation could be obtained without a commutator while employing direct current. The meter had an electromagnet whose central pole was surrounded by the other pole, producing an intensive cylindrical magnetic field. A copper cylindrical vessel, insulated inside, was mounted over the central magnet so that it did not touch and was supported by a pivoting spindle that rested in a depression at the magnet pole's top. The depression was filled with mercury to insure good current conduction. Attached at the lower rim of the copper cylinder were fans or paddles (the latter to act as a retarding force) which rested



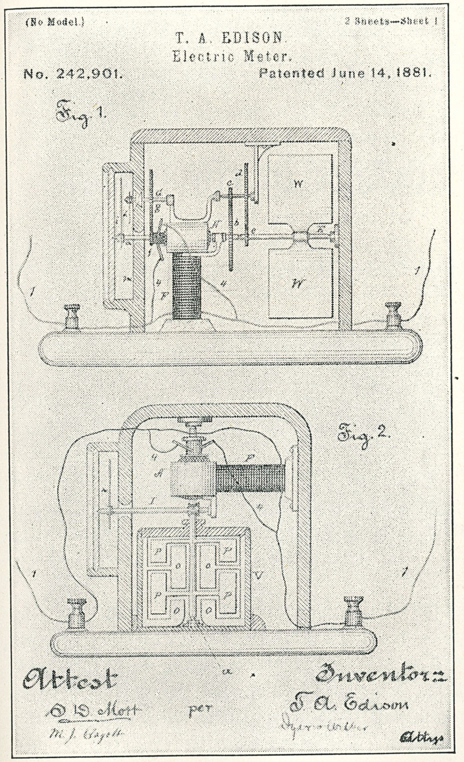
Another diagram from Jehl's treatise illustrating method of adjusting compensating resistances.

part way in a round trough of mercury. Thus, when the electromagnet was energized and a current passed from the center at the top of the copper cylinder down into the mercury trough, the cylinder revolved according to Amperian laws.

As I have already mentioned, Edison received twenty-two patents on meters.(3) Although most of them were never developed to practical use, some of the ideas are interesting and instructive.

The simple electrolytic meter was the one that rendered such valuable service in the pioneering days when the Edison complete system was being introduced. Many years were needed before other inventors could produce a meter able to force its retirement.

In the museum of The Edison Institute at Dearborn many such pioneer meters may be seen, having been donated by several electric light companies as well as by Edison.



Mott's drawing of the electric meter. From Edison's patent office application.

(3) *Numbers 240678, 242901, 248565, 251545, 251557, 251558, 265774, 281352, 293435, 304082, 307030, 307031, 370123, 406824, 406825, 425760, 476990, 484183, 659389, 660293, 663015; 703051.

Original photograph of Edison's laboratory at Menlo Park, 1877.

LXXII. Workers in the Shop

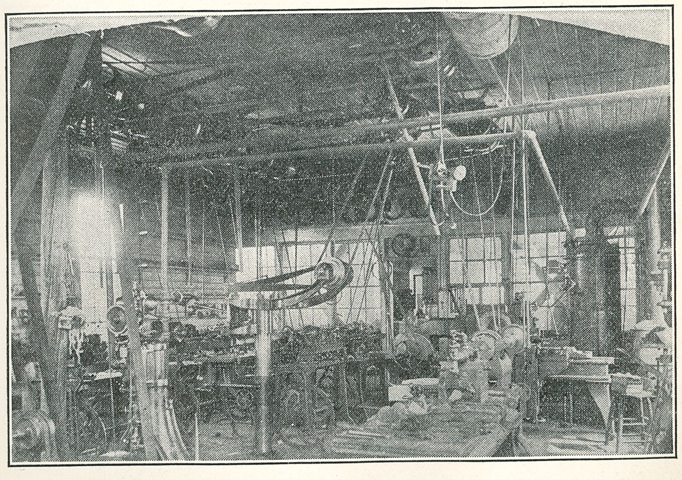
I WISH to say a word about those brave men and women who work in shops and factories, that vast army of toilers that make for us almost everything we in one way or another consume. With the things they produce they furnish also in great measure the means for advancing intellectual potentialities of other men that often transform them into apostles of literature, science and art. Take away shops and factories and we shall recoil to the dark ages. The shelter and comforts of our homes are the products of these establishments, as also all our means of transportation. The two unknown geniuses who laid down the fundamentals of civilization were the discoverer of fire and the inventor of the wheel.

It thus behooves us to inspire youth with a sense of the beautiful in useful crafts that form the essence of civilized communities. The youth who masters a craft has a background that sustains him in life, and if he possesses a fine mentality besides, he soars to success as a self-made man. The opportunities presented to the youth of today are far more numerous than they were fifty years ago. Many new industries requiring the services of all grades of men have recently been created, the like of which was never dreamed

of in the days when Edison founded the electrical industry.

Most of the world's great men have been craftsmen who created through the manual arts utilities of the highest benefit to mankind. No better example can I give than such men as Edison and Ford. Edison solved the problem of harnessing and transporting electrical energy; Ford solved the problem of general transportation; both laid the foundations of the world's greatest present-day industries. Both loved the shop with its merrily chattering machines and the fine men working them as they turn out useful things. I remember happily all the intimate incidents of the shop involving Edison and the boys, and the close and appreciative friendship that existed between them. (And many of those craftsmen rose to eminence.) I have seen the same fellow spirit exist here in the Greenfield Village Edison laboratory machine shop between the founder and his men. Machines, and especially machines in action, charm Henry Ford, whose love for mechanical and chemical processes resembles Edison's.

At Menlo Park Edison had two machine shops. The first was on the ground floor of the laboratory in the rear. Here Kruesi was foreman as also in the little shop, and here Edison's conceptions of the transmitting carbon telephone, the

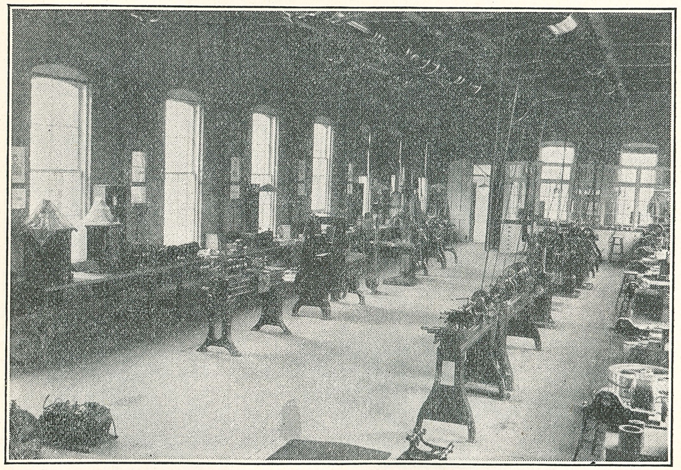


First Menlo Park machine shop—rear of laboratory (from original photograph). Now restored at Dearborn.

carbon, condenser and the dynamic microphone, together with the phonograph, were worked out. The historical importance of this little shop led Henry Ford to arrange its restoration, with Edison's assistance, in the Menlo Park compound in Greenfield Village. Edison contributed the old lathes and other machines. When he visited Dearborn, it always delighted him to go to the little shop with Mr. Ford and reminisce about the old days, both men sitting on stools at the workbench.

On one of these occasions our old Menlo Park friend, Charles L. Clarke, was also present and I am sure he has not forgotten the animated conversation between Edison and Ford on machinery.

The little Menlo Park laboratory machine shop was in action from 1876 until the latter part of 1878, when all its machines and tools were placed in the newly erected brick shop some seventy-five feet away in the rear of the laboratory. The new shop and the engine and boiler rooms were all in one building, the shop being about ninety-two feet long and twenty-eight feet wide, and the engine and boiler rooms thirty feet long and thirty-nine feet wide—the whole well lighted by thirty large windows. The entire length of the



Interior of brick machine shop, as restored at Dearborn. Note portraits of workmen above benches along the wall.

building was thus one hundred and twenty-two feet. It was equipped with ample machinery and tools so that Edison could make heavy experimental models of electrical generators. While the shop would have done credit to any manufacturer of that period, the work actually done there was devoted solely to organized research. Today when you enter the old place as restored in Greenfield Village, your eyes are likely to see the framed tribute to the men who once worked there. It reads:

> 'We pay tribute here to those silent workers at the bench who shape out of Nature's materials the forms that serve mankind.
>
> 'In the history of Edison's great achievements, the Edison machine shop played its conspicuous part.'

Respect is further paid to those fine mechanics and instrument makers, whose meritorious work aided the master, by the placing of their portraits on the wall at the spot where they once worked. A printed placard is under each picture, in accordance with Mr. Ford's purpose to give the special worthies their due. He has suggested the same plan in honoring the special men who once assisted Edison in the laboratory.

In the early days in Newark, Edison always sought high-grade artisans. Among such workers were Sigmund Schuckert, Sigmund Bergmann, Charles Batchelor, John Kruesi, Charles Dean, James Bradley, Gustav Ritter, Henry Thau, John Ott, David Herrmann, Ungar, Wendelbow, Hinze, Muller and others. Many of these were experts once employed with Brown and Sharp, or Pratt and Whitney. Some possessed exceptional abilities through which they cut brilliant careers for themselves and became well known in the pioneer history of the art.

When Edison left Newark to settle down at Menlo Park in 1876, some of his men came with him. Batchelor and Kruesi started the Edison Electric Pen Factory in a building that was situated some distance from the laboratory near the tracks of the Pennsylvania Railroad. The same building was later, in 1880, fitted as the first incandescent lamp factory in the world; for the electric pen was not long manufactured at Menlo Park, Edison having made arrangements with the

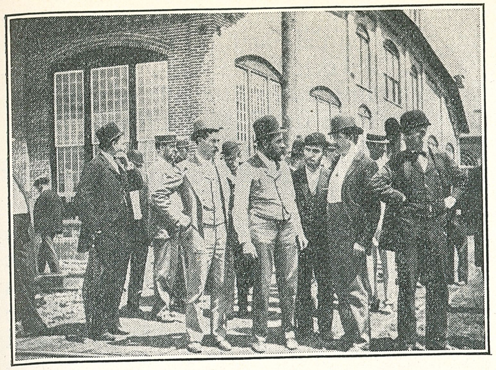
Western Electric Company, of Chicago, to undertake its production and distribution. (The pens came into circulation everywhere here and abroad and more than sixty thousand were made and sold.)

Batchelor then came to the laboratory and assisted Edison on the second floor. Kruesi took charge of the little laboratory machine shop. Carman and Griffin occupied the office on the ground floor in the front of the laboratory. Toward the end of 1878, things changed again and Kruesi with his men, James Bradley, Charles Dean, Thomas Logan, John Ott and a few others, all moved to the newly built machine shop, as related above, and Carman, Griffin and Johnny Randolph to the new office and library building. And so the whole laboratory building became devoted to experimental research work.

At the large machine shop Kruesi was again intrusted with the foremanship, for this sturdy Swiss was a man of remarkable character. He knew how to handle not only the old Edison men but also newcomers. He gave his orders in a quiet but determined manner that caused no rancor. His ability as a mechanical engineer and his habit of pushing forward, together with a marked initiative, all of which are so necessary for success in life, were qualities that Edison prized. Kruesi had a talent for making any piece of apparatus or machinery from the roughest sketch in a way that was always satisfactory to Edison. There existed in him qualities that make a man at home in any circumstance and enable him to handle important things as well as trivial ones at any time and in any emergency.

In general, mechanics or instrument makers who can work with precision only from draftsman's drawings would doubtless succeed much better in life if they had the power to work independently of help. Self-reliance and positive determination form the motto of great men who, with other superb qualities, triumph over all obstacles. In the laboratory as well as in the machine shop there were men who possessed more or less of this talent for aggression, and these men were all intrusted by Edison with special commissions when commercial manufacturing and the introduction of the Edison system began. Others who were good craftsmen though limited in ideas and helpless at self-starting simply continued with the crowd and were pushed along with it.

As soon as Kruesi had finished what tools and other things



John Kruesi in center of group of workmen at Schenectady.

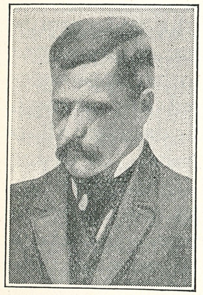
were needed for the first incandescent lamp factory and had completed all arrangements for Charles L. Clarke to run his final economy test of the Edison system, he left for New York City. There he installed the Edison Underground Electric Tube factory at 65 Washington Street and soon had it on productive basis. With the underground electric tubes, Kruesi had to work out a system of connection boxes, junction boxes, safety catch boxes and other appliances, for the making of which Edison only directed him through rough sketches. Kruesi put this system in standardized shape and in different sizes. He was the mainstay when the system was placed in the streets of the first district lighted from the Pearl Street central station. The work was only allowed to be done at night and Edison and Kruesi were ever there on the job directing personally. Many are the tales of those pioneer nights, some serious and others humorous, while the bedding for that underground system was being laid.

The Edison Electrical Tube Company later moved its shops to Bridge Street in Brooklyn and after a short time was absorbed by the Edison Machine Works. This was in the latter part of 1883. Charles Batchelor was then the general manager and Kruesi became the assistant manager.

With the coming of labor trouble, Edison in December, 1886, moved the machine works to Schenectady, using buildings there formerly occupied by the McQueen locomotive works. And when all Edison interests became merged into one company in 1889—the Edison General Electric Company—Kruesi was made general manager. He also retained his position after the consolidation of the Edison and the Thomson-Houston companies under the name of the General Electric Company in 1892. In 1894 he was made consulting

engineer of the General Electric Company, which position he held until he passed away on February 22, 1899, loved and honored by all. His loyal devotion to Edison and the untiring work he did for the cause make him one of the most conspicuous figures to come from the Edison machine shops. He rose not only to be an associate of Edison but a partner, and his aid in the introduction of the Edison system was of inestimable value to his chief.

There were plenty of opportunities for Edison's mechanics in those days and men possessing the go-getting instinct got their chance without fail. There was Charles Dean who was one of Edison's Newark men, a sort of superintendent of the mechanics and tool makers, succeeding Bergmann, who had already advanced to be inspector of the Gold and Stock instruments Edison was building. At the old Menlo Park machine shop Dean worked at the bench although he was one of the oldest shop hands there, having come before Kruesi. He had all the fine mechanical abilities necessary for a leader, and today as I look back to those days and reconsider the matter, I am inclined to believe Dean was in every respect the equal of Kruesi as a mechanic. Like Kruesi, Dean could execute from verbal explanations or rough sketches anything Edison wanted, and it often happened that Edison would go directly to one of his old hands and have something made without first conferring with Kruesi. Dean also possessed other remarkable qualities that fitted him for great work and would have in themselves elevated him to a position of responsibility. He was a hustler by nature, and he had a figure that was bound to command respect. Edison held him in high esteem, and although he would now and then cause provocation, the chief would close an eye, hoping that he would ultimately settle down.



CHARLES DEAN

Dean lived with his wife and grown-up son George—who also worked in the machine shop—in one of the twin two-family houses diagonally opposite the laboratory. The other house was wholly occupied by Mrs. Sarah Jordan as a boarding and rooming house. The house where Dean lived also accommodated another family, with whom Charles L. Clarke

roomed, though he took his meals at the Jordan boarding house. As the wall partitions were very thin, I have often wondered what Clarke thought on those Saturday nights when the sound of falling crockery and crashing utensils could be heard coming from Dean's house.

Well, at last affairs came to a climax with Dean; Edison told him to settle down, or quit. Dean reformed, and from that time on was a changed man. Edison was more than satisfied, for he had a great thing in store for him.

It came early in 1881, when he promoted Dean to the position of superintendent of the Edison Machine Works at 104 Goerck Street. This was a big job; for the works were to turn out the different sizes of Edison's generators including the jumbos, some of which were to be sent to the Pearl Street station in New York City, and some to Paris, London, Italy and South America. Dean did fine work in getting the works in running order and soon the Edison 60-A-lamp dynamos were ready and work was commenced on the first commercial jumbo dynamo which, when finished, was sent to the great Paris International Exhibition of Electricity. The jumbos that followed were also made under Dean. We must not forget that here was a new industry that had to be created in all its details at a period when nothing else existed like it. It may be mentioned that all the working drawings were made at the Edison headquarters at 65 Fifth Avenue, New York City.

These drawings, together with those of other apparatus, were all made under the supervision of Charles L. Clarke who, as I have mentioned, was the chief engineer of the Edison Electric Light Company. The work that Clarke did day and night in those stirring months of production was of a super-erogatory nature. In fact, his bedroom was located at headquarters. Thus we see that his preparation of all those pioneer drawings for Dean constituted one of the links of success in the starting of the Edison system. Dean, on the other hand, in following out the details of the drawings as a master foreman, also deserves credit for work well done.

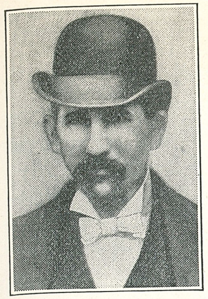
After I had finished the special experiments I was conducting at Menlo Park while Edison was in New York City, I went to the Goerck Street Machine Works in New York City and installed the first commercial testing laboratory for dynamos, lamps, etc. There I came in contact again with Dean and had a better opportunity than ever to study that

singular man. As superintendent of the Edison Machine Works, Dean was a changed man. He had donned stylish clothes, loud neckties and a diamond breast pin: about him seemed to float a halo of prosperity. He reminded me of one of the higher ward politicians. Equally changed was his manner of handling the men in the large works. He was bossy by temperament, and at the works he soon developed the trait as an art. It was a revelation to see him direct his men according to the custom of those days. Because he was always fair-minded—and understood his job, being an expert in mechanics—he retained their respect though stern with them. If one of his men did another a mean turn he would give the offender a welting and then send him back to his job, as a father a naughty boy.

In spite of the difference between his nature and that of Kruesi, Dean attended to his business, and the works hummed under his management. He was the first to put the art of producing dynamos for incandescent lighting on a stable factory basis from the pioneer workshop point of view. He was a shop technician; theory, when necessary, was pounded into him by Edison, Clarke or others. He would have attained great success in life if fate had not decided otherwise. It was while I was in Vienna that one of my Menlo Park colleagues wrote me that Edison had suddenly discharged him, because of some misunderstanding.

My friend wrote that even Edison did not relish the idea of going down to the Goerck Street Works to do the job but left it to Sammy Insull, his secretary. Insull, on the other hand, felt pretty much embarrassed, for he was well aware of the John L. Sullivan propensities of Dean. Scratching the back part of his ear, he thought out a plan for executing the order with the aid of two of the huskiest cops of the precinct. I was sorry about Dean; for his managerial ability in starting the Edison Machine Works contributed its part to the early introduction of the Edison system. McDougall then became superintendent.

Another of our fine mechanics at the Menlo Park machine shop was James J. Bradley. He had served Edison during the early days at the Ward Street shop in Newark, and later was a member of Kruesi's staff in the little machine shop of the laboratory in 1877. When the large shop was built at Menlo Park, Bradley was transferred to it and there proved, among other things, his skill in making apparatus to be



JAMES J. BRADLEY

used in fitting up the Edison Lamp Works. In the summer of 1880, Edison made him master mechanic of the lamp works and, later on, foreman of the raw bamboo department. Here Bradley helped to establish the mechanical details necessary for cutting down bamboo to a filament before carbonization and in working out a practical shop system.

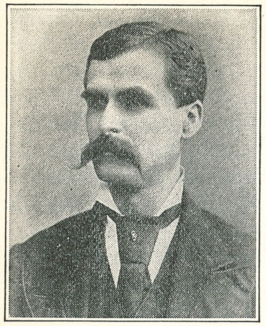
When Edison moved his lamp factory to East Newark—called Harrison today —Bradley installed its bamboo department and remained with the works as master mechanic until 1893.

John F. Ott was another bright and industrious worker coming to the Menlo Park machine shop from Edison's Ward Street shop in Newark. Ott was an expert mechanic to whom Kruesi generally confided the making of the more delicate apparatus or instruments required in research work at the laboratory. He was a pleasant and agreeable man, and though he had plenty of opportunities like others at Menlo Park, for he was a master of the trade he plied, he remained content in the sole ambition of loyally serving his master as fine-instrument maker.

When Edison left Menlo Park in 1881, and a little later when Bergmann and Company moved to their larger quarters at 17th Street and Avenue B in New York City, Ott became a sort of confidential experimental instrument and model-maker for Edison in the temporary laboratory installed on the top floor there. When Edison moved his laboratory to Orange, New Jersey, Ott followed and retained the same position.

JOHN F. OTT

Although Edison had a large shop with many expert artisans in Orange, Ott performed his special work in a separate little shop. He worked for Edison all his life and when he became disabled, was retired and pensioned. When he heard of the passing of his great master on October 18, 1931, the



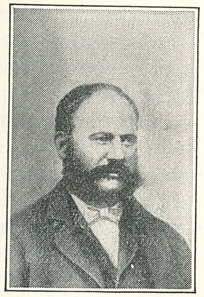
THOMAS LOGAN

shock was too much for his enfeebled body and he died on October 19, 1931.

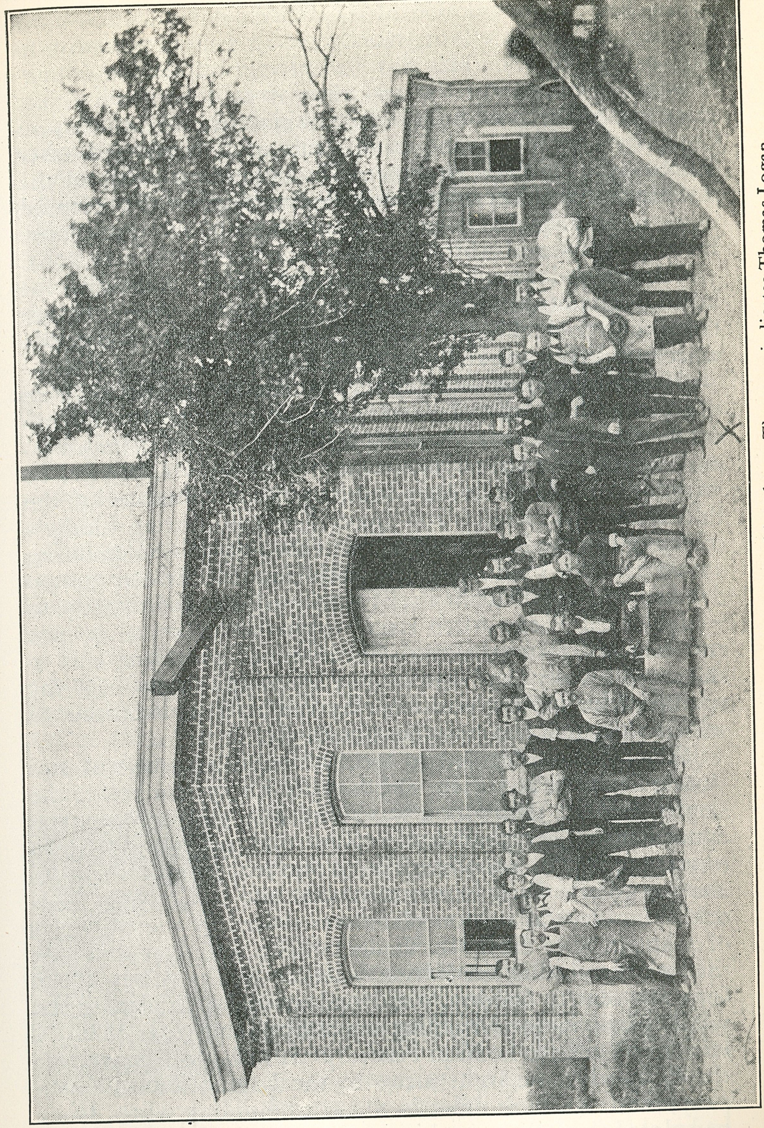
Thomas Logan was another of the able mechanics clustered about Edison at Menlo Park. He was on the Kruesi staff back in 1877 when Edison had but the little shop on the ground floor of the laboratory. Logan was a fine, quiet man to whom some of the boys gave the nickname of 'Gentleman Tom.' I have heard it said that Kruesi intrusted him with the making of a part of the original phonograph. Logan's excellent craftsmanship was highly appreciated by Edison, and he was often given delicate pieces of work to do where precision was of paramount importance.

The esteem which Edison had for Logan is clearly exemplified in his making him foreman of the machine shop when Kruesi left for New York City. This happened on February 14, 1881, and the boys all congratulated him and thought that St. Valentine was surely good to him. Although some had left the shop for the New York work, Logan had plenty to take care of—often special work from Edison, Clarke and others from the headquarters at 65 Fifth Avenue. Edison used to send him his usual rough sketches, accompanied by only a few words of explanation. Some of these original orders and notes may be seen in Dearborn framed on the wall by the bench where Logan worked in the Edison Laboratory Machine Shop. Logan was a brother-in-law to William Carman, our bookkeeper. Like many of our old Menlo Park friends, he passed away early—May 14, 1887.

From among other good men on Kruesi's staff, I must not forget honest David Cunningham, who was not only a fine mechanic but an expert machinist. Edison sent him to assist Batchelor in erecting his machinery exhibit at the International Electrical Exposition held in Paris in 1881. There Cunningham



DAVID CUNNINGHAM



Original photograph of the Menlo Park brick machine shop. The cross indicates Thomas Logan.

superintended the erection of the Edison jumbo, 1,000-light dynamo and boiler plant which created such amazement in engineering circles. He also had charge of the other machinery at the exposition and then went to Ivry-sur-Seine, just outside Paris, to help Batchelor start the French Edison Company's works for the manufacture of dynamos and other Edison apparatus. I was there at the time to assist in the installations and I bear witness that Cunningham did splendid work in getting the shops in shape to build the machinery. In fact, I was surprised to see the self-starting spirit he evinced.

John Hood was another of the capable machinists at Edison's command in the Menlo Park machine shop. It was Hood who took charge of the Brown steam engine and boiler when it was erected at the end of 1878.

He had the honor of being the first steam engineer to direct the power from the steam engine for running the Edison dynamos during the world's first demonstration of an incandescent lighting system at Menlo Park (1879-80). Likewise, he attended to the machinery running the exhibitions of the Edison electric railway and again that used during Clarke's economy tests and the exhibitions of the Edison system during 1880-81. Hood also ran the experimental Edison jumbo dynamo (built at Menlo Park) that was attached directly to a high-speed Porter-Allen steam engine all mounted on one cast-iron bed plate, the first self-contained generating unit in electrical history, and the largest up to that time. At the restored Menlo Park you may see the brick foundations to which this unit was once anchored.

When Edison decided to erect an exhibition central station in London, and there demonstrate his system before the English public, John Hood was selected to put up the jumbo dynamo machinery and boiler plant and get everything in running order. To assist him Edison also sent James Holloway, another Menlo Park expert mechanic and machinist. This exhibition central station plant was placed in the basement of a house at 57 Holborn Viaduct. The second jumbo unit that was finished in the Edison Machine Works in New York City was sent to London, and Hood succeeded in placing the whole plant in good running order by January 12, 1882. I left New York for London February 22, 1882, to demonstrate the Edison electric light meter to the English Edison Company, who had their office in the same building where Hood had placed the Edison machine plant. While there I inspected

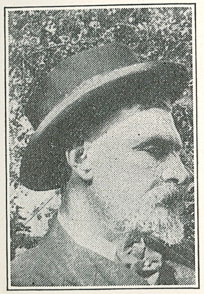
Hood's work several times and bear witness that he and Holloway had performed a fine job and greatly contributed to the success of that plant. Some of the gentlemen of the English Edison Company also spoke warmly of the two capable Americans who had placed the machinery plant in such splendid order.

Another jumbo unit, No. 3, was later added, and on April 11, 1882, the station was officially opened for inspection and demonstration by Edward H. Johnson, Edison's representative in London then. I must mention here that Johnson was assisted by William J. Hammer, who had charge of the electrical part of the plant and performed his part most admirably.

Edison was so pleased with Hood's accomplishment that he was called back to America later to take part in the work that was going on at the Pearl Street Central Station in New York City. Hood started the jumbos there on September 4, 1882. And thus he had the signal honor of putting into action the first important central electric lighting stations in history.

James Holloway remained in London, where in 1882 another jumbo unit was added to the Holborn Viaduct plant. This continued until about 1884, when, having served its purpose, it was dismantled.

I have already mentioned in former articles some of the facts concerning William S. Andrews, who became one of Kruesi's staff at the Menlo Park machine shop in the latter part of 1879, just as Edison was preparing to demonstrate his lamp and system. Andrews was one of those fine mechanics whose ability in his craft came useful to him in several ways. He had some theoretical knowledge and took more than common interest in the apparatus or other things that Kruesi gave him from time to time to make. When Edison set me to work making experimental determinations for his chemical, or electrolytic, meter, Andrews was selected to make the apparatus I desired for my tests. He was also skillful in making many of the more delicate pieces for tests or research work at the laboratory. Andrews possessed agreeable traits

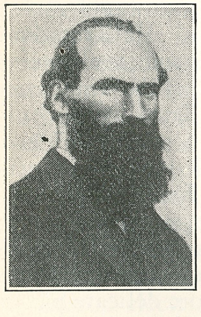


JAMES HOLLOWAY

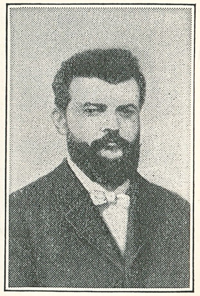
that created friendships and he was liked by all; he remained at Menlo Park for quite a while after Kruesi had left, assisting Thomas Logan, the foreman in Kruesi's place. He was of a studious nature and employed every opportunity of advancing himself in theory as well as in practice.

Later on I installed and had charge of the testing room at the Edison Machine Works at 104 Goerck Street. On February 22, 1882, Edison sent me to Europe and I learned later that Andrews had succeeded me in the testing room. In July, 1883, Andrews and Frank J. Sprague were sent to Sunbury, Pennsylvania, to install the first three-wire (overhead) plant. Edison remained at Sunbury for some time, watching and studying this first three-wire system in practical operation. Andrews was active in installing other small Edison central stations in different parts of the country until about the middle of 1886, when he left the service to accept a position elsewhere. In 1889 he re-entered Edison employ, however, and, with the exception of one year, always thereafter remained connected with the Edison General Electric Company, or the General Electric Company when the latter succeeded the former. In 1913 he entered upon the position of consulting engineer of the General Electric Company and there in Schenectady devoted himself to research work. He died in 1929 from the slow but fateful effects of X-ray burns received while experimenting with rays a few years after Roentgen made his great discovery in 1895.

I have also in former articles mentioned John H. Vail, who was added to Kruesi's staff about the middle of 1880. He left after a short time but returned in the following October. Vail had a good general knowledge of machinery and possessed an amount of intuition that placed him at ease wherever he was. He was not afraid to tackle any job placed before him. After he had famil-



First 'unknown' workman whose picture is still unidentified.



Second 'unknown' workman.

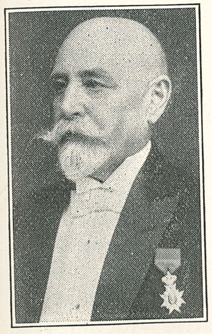
iarized himself with the Edison dynamo, he was given charge of the battery of dynamos that supplied current for Edison's second and last demonstration at Menlo Park during 1880-81. Edison, pleased and satisfied with the manner in which Vail took care of the dynamos, intrusted him with the erection of the plant at 65 Fifth Avenue, the New York headquarters.

As he became more and more versatile in the details of the Edison system, he erected many isolated plants, and eventually small central stations everywhere. He was also interested in other work, being very prominent in the affairs of the Association of Edison Illuminating Companies, of which he was one of the early secretaries. Like the other boys who remained in America, he served the Edison cause admirably. His name is on the first edition list of Edison pioneers in incandescent lighting who all hailed from Menlo Park and who taught others to follow their lead.

Two other fine mechanics at our Menlo Park machine shop had been once employed in the first small shop. Their names as well as their activities after they left us are forgotten; yet because these craftsmen were notable for the excellence of their work, we pay them tribute as the unknowns No. 1 and No. 2.

Among the other good men at the machine shop was Alexander Mungle. When the work at Menlo Park was finished, he became interested elsewhere and eventually, with Edisonian resolution, started an engineering shop of his own.(1)

There was a fine instrument maker by the name of Hugo Andersson who likewise had the self-starting spirit. Andersson was formerly engaged in making physical instruments at Bergmann's shop on Wooster Street in New York. Specimens of his work came to the attention of Edison, who greatly admired its peculiar beauty of line. While our other fine instrument makers turned out good work—satisfactory, at least, for research purposes—and perhaps there was no need for the fancy finish that Andersson always gave, Edison nevertheless requested Bergmann to let



HUGO ANDERSSON

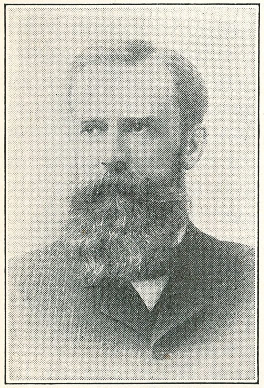
(1) Mr. Mungle passed away on January 1, 1938.

him have this exquisite artisan. He came to the Menlo Park machine shop in the early part of 1881, just after Logan was made foreman. Edison was already in New York City but came over to Menlo Park every now and then. He set Andersson to making some specially fine apparatus that he wanted to place in his exhibit at the Paris International Exposition of Electricity which was to open its doors in a few months.

Andersson was one of those artistic craftsmen who when given a job, whether for experimental or for permanent use, always turned it out as a finished piece—often in the same length of time as others took to turn out a rough experimental model. Andersson had also business and other qualities that a man requires for getting on in the world and these he put into effect when he returned to his native land, Sweden. He founded his own business and toiled hard, and his expert work as well as his activities in general were recognized and appreciated by his king and country.

Other fine machinists were the Westerdahl brothers, who also came from Sweden. Anton came to Menlo Park in 1880 and Alex in 1881. Both did their part while at Menlo Park.

Another of our clever and conscientious men was H. V. Campbell, a young carpenter and contractor from Metuchen, New Jersey. He came to Menlo Park in October, 1878, and took part in the construction of the office and library building as well as the machine shop and the shed that was later called the Little Glass House. Campbell was an expert in carpentry, one of those master carpenters seldom met with in these days of standardization. Kruesi, who had charge of the carpenter and pattern shop (located between the laboratory and the machine shop), knew this and intrusted Campbell always with any special work ordered by Edison. He built the wooden tower by the laboratory where Edison first made experiments in the magnetic separation of iron from sand. When Edison began to put into effect the idea of an electric locomotive using his 90% efficient constant potential dynamo, Kruesi gave Campbell a gang of men to grade the roadbed and place the sleepers, which were of Virginia cordwood. He did other work for the road, such as (if I remember rightly) making the trestle for the first road and doing the carpentry work on the locomotive, the flat car, the open trailer and the 'Pullman' that made up the train. When the boys would see Campbell and his gang, they used to say, 'The Campbells are coming.'

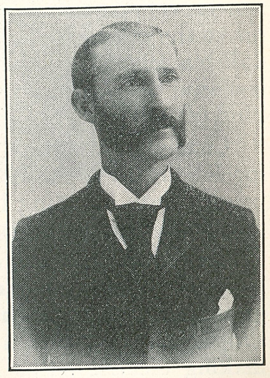


H. V. CAMPBELL

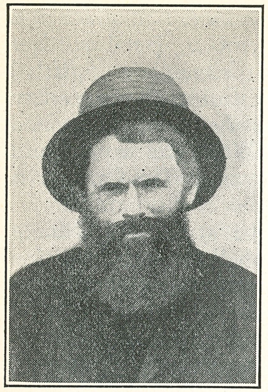
Later, when Edison decided to give a last big Menlo Park demonstration of his system, Campbell built the wooden annex shed by the engine room for housing the eleven dynamos, the shafting, pulleys, etc. He also placed in position the exhibition lamp posts and the troughs and other equipment for the first underground conductors laid by Wilson S. Howell.

When Edison decided to build the first incandescent lamp factory, he chose to use the building where the electric pens were once manufactured. Campbell with his helpers was given the job of making all the alterations and extensions as well as much of the wooden apparatus and many of the utensils; in fact, he became the master carpenter of the lamp works. The Menlo Park Lamp Works under first Batchelor and then Upton, were in operation until April, 1882, when they were moved to East Newark (Harrison). Here Campbell again did his part in the construction work.

In August, 1881, he went to New York City and had charge of the construction work at the Pearl Street central station. For it may be mentioned that wood was very liberally used in those days because it was considered a good insulator. Though a heavy iron structure of girders and columns similar to the system used in elevated railroads was installed there by Edison's mechanical engineers for supporting his engines and jumbo dynamos, Campbell had plenty of wood work to do in the station. Like others at Menlo Park, Campbell took advantage of the opportunities offered and, being a man of initiative, gradually switched



CHARLES W. MOFFETT



MILO ANDRUS

into the electrical part of the business. He remained with the Edison interests and was superintendent of the second district of the New York Edison Company until his retirement in 1935.(2)

The carpenter shop also employed two pattern makers, Milo Andrus and Charles W. Moffett, or 'Charley,' as Edison called him. Both were old trusted hands who had been with Edison before he built the brick machine shop and continued in his service for some time after he left Menlo Park.

Charles W. Moffett lived with his family at Menlo Park; he was a Civil War veteran and a good pattern maker. His home, which is still standing there, was close to Mr. Edison's laboratory. Mr. Edison rigged up a bell from his shop to Charlie's bedroom window, so that if there was need for a new pattern idea during the night he could summon him.

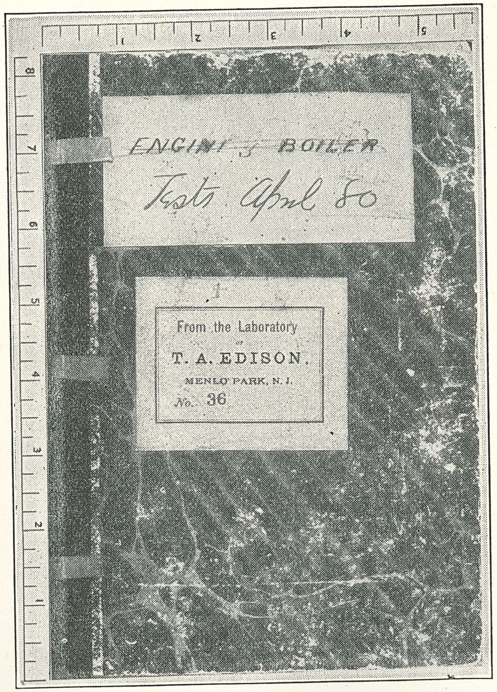
When the factory moved to Harrison, New Jersey, Moffett brought his family and settled there. He continued to work for Edison and after a time had his own small shop on 7th Street in Harrison, where he made wooden fluoroscopes. As I recall seeing them, they were about twenty inches square and tapered back where there was a piece fitted with black fur at the edge for the eyes. The whole thing was painted a dull black, and as I understood it these were the frames for a machine to see the bones in the body. He was busy at this kind of work for Mr. Edison for a number of years.

Charles W. Moffett's oldest son, Benjamin, went to work for Edison at Menlo Park at the age of fourteen as an apprentice boy, learning how to blow bulbs. For a while they made only one good lamp a day.

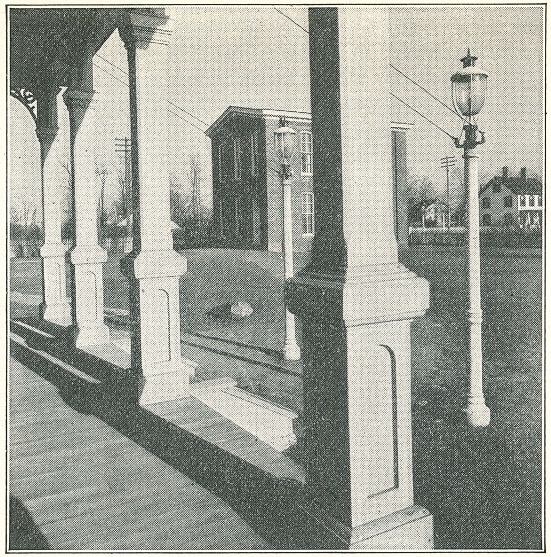
Benjamin Moffett continued working in the shop at Harrison after they moved from Menlo Park, blowing the glass bulbs for the lights. Eventually he had his own small shop in Kearny, with a few men to help, where he continued making electric bulbs for Edison.

(2) Mr. Campbell passed away April 4, 1938.

Years afterward the Edison company devised ways of making the bulbs by machinery, and then Moffett went into the work of making all sorts of medical tubes (glass), tiny bulbs, etc., that required skillful hand work.



Cover of one of Edison's laboratory notebooks, dated April, 1880.



Restored office and library building viewed from Menlo Park laboratory.

LXXIII. Edison's Office and Library

I HAVE already casually mentioned the office and library building that stood in Menlo Park. I shall now speak further of it and tell the interesting story of how it came into being.

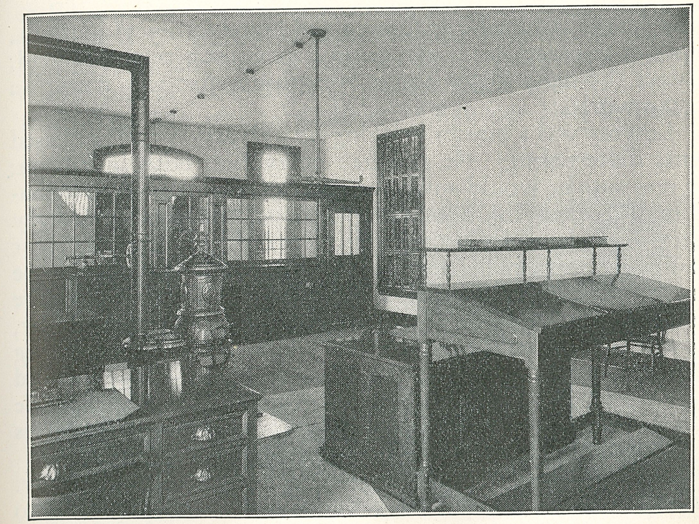
When Grosvenor P. Lowrey had settled financial matters for the Menlo project and 'The Edison Electric Light Company' had been incorporated (on October 15, 1878) for 'producing light, heat or power by electricity,' he had a long talk with Edison. The money being now assured for backing up the costly experiments, the necessity was impressed upon Edison by that celebrated jurist of starting in a large way, with plenty of margin in every direction for the

future. Edison was told he must build a large, solid machine house of brick, and equip it with the best machinery, tools and men; he must have an engine and boiler capable of producing power for all emergencies as the work advanced and must not stint himself in any way.

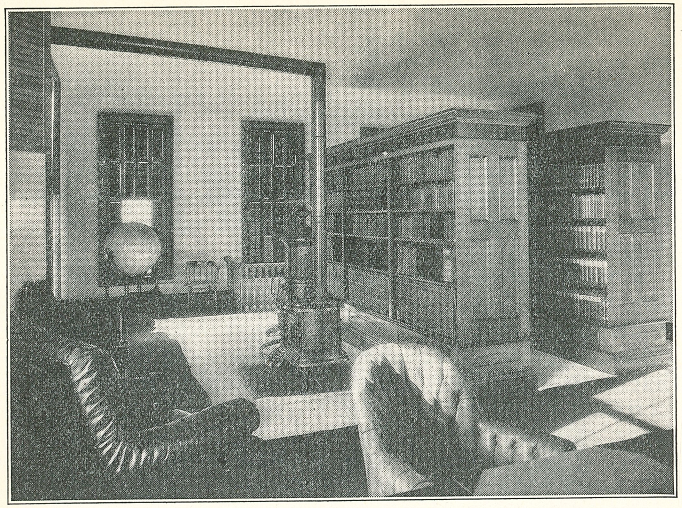
Edison was surprised. He had never contemplated beginning on such a grand scale. He had estimated, he confided to Lowrey, that a machine shop housed in a clapboard building with a small steam engine of about twenty horsepower would be sufficient.

Lowrey mentioned, moreover, that there must be a two-story brick building to be used as an office and library—at which Edison again appeared surprised. 'What's the matter,' said he, 'with my office on the ground floor of the laboratory? That is large enough for the purpose, and I can cram all the electrical books that exist on a few shelves there and have plenty of room left.' Edison said he already possessed the books; that what they contained was nothing new to him; and that, besides, all these things would cost lots of money.

Lowrey smiled calmly and told Edison he must procure



Lower floor of office building looking toward front. Shows partition, bookkeeper's desk and coal heater.



Part of second floor showing Edison's library. Globe in corner.

more books, subscribe to foreign and home technical journals, buy the transactions of the learned societies here and abroad; in fact, he must know about everything that was going on in the world.

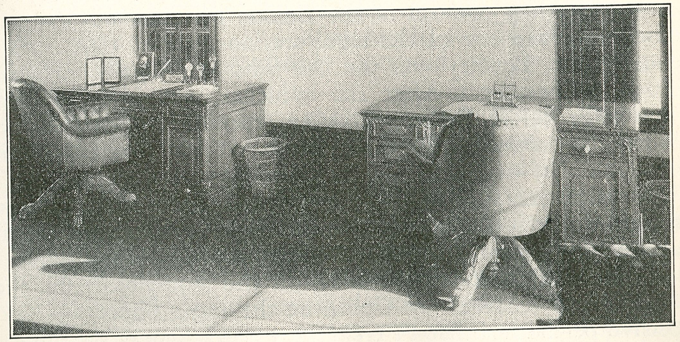
Lowrey was a master in sizing up a situation and possessed acute discernment. He also had an explicit faith in Edison; he was sure he would solve the great problem of the distribution of current for domestic purposes. As I have already mentioned elsewhere, Lowrey was a master coach and director to Edison in such matters and his counsel was always wise and effective. So he told Edison that a dignified separate building for his office and library was absolutely necessary, not only for himself but for the gentlemen who were backing the venture. And no doubt many distinguished visitors would be coming to Menlo Park who must be received in a respectable place. He talked as if he already foresaw future events as they really happened later on.

He laid Edison's fears concerning expenditure of money. He told him he must strike while the iron was hot—and to rest assured that all expense incurred while launching a work in anticipation of a successful issue would be easily liquidated.

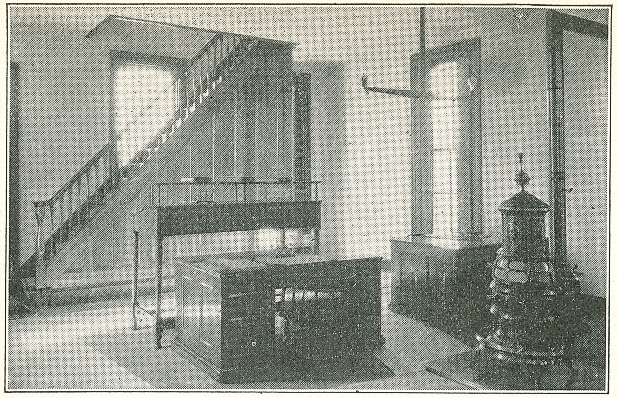
The newly formed company had intrusted the Lowrey firm (Porter, Lowrey, Soren and Stone) with the auditing of all expenses that should be incurred by Edison in his domestic light problem. Lowrey knew that he could pass anything reasonable before the board of trustees, which included himself and three other members of his law firm. Thus it happened that the two additional buildings erected in the compound—the machine shop and the office and library building—were of such substantial character. They were built to last ages, although they were only used by Edison for the few years leading up to the completion of the great task he had promised to do.

Lowrey went further and had Edison procure the best office furniture possible, which must be of polished cherry wood just like that in his law offices in the Drexel Building in New York City. In fact, the library and office building from the start produced an imposing impression on all who entered: one felt translated for the moment to Wall Street itself. Lowrey insisted that an underground vault be constructed by the side of the building where valuable documents and other things could be placed for safe-keeping.

Another stroke that Lowrey's fine judgment contributed to Edison's efforts toward reaching his goal was his selection of Francis R. Upton as mathematical assistant to Edison. As I have already said in other articles, Upton was a brilliant young man of New England pioneer stock who had studied at Phillips Academy in Andover; Chauncey Hall in Boston;



Front of library as restored. Right—Edison's desk; Left—Griffin's desk.



Another view of ground floor as restored at Dearborn, showing stairs mounting to second floor.

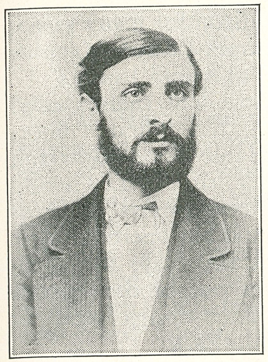
Bowdoin College; Princeton University, and Berlin University in Germany, under Helmholtz. While abroad he had acquired some knowledge of German and French. That was what Edison needed; for with the library stocked with books, transactions of learned societies, journals from here and abroad, some in foreign languages, Upton often delved into them.

This recalls to memory a paragraph in a letter written to me by Charles L. Clarke regarding Upton as an Edison assistant. He said: 'I am reminded of a remark by Lowrey to Seward (leading counsel in the Edison filament suit) in my presence during one of the legal sessions, about 1891. As I remember it, Lowrey was the one who got Upton into the Edison laboratory. After the evidence was in as to the knowledge before Edison, Lowrey, turning to Seward, exclaimed in substantially these words: "My! but wasn't it fortunate that we got Upton to assist Edison when we did!" The implication was at the moment that Upton kept Edison straightened out and correctly informed on underlying physical laws for Edison's inventive ability to work upon.'

From this, without dwelling on the side involving the valuable aid rendered by Upton at the most important and decisive period in Edison's creative research work, we obtain further conclusive evidence of Lowrey's master staging of

that great Menlo Park drama. He was certain beyond all doubt that the drama would be a world hit, with Edison in the star role and a loyal cast supporting him.

The library was often the meeting place of learned men of those times. To this day I can visualize them all. They would come to Menlo Park, examine the work and view the progress made, after which they would adjourn to the library and discuss matters until it was time to leave for the railroad station. It was in the library that Sarah Bernhardt with her retinue was received by Edison when she came on December 5, 1880. I remember also the visit of Lady Macdonald, whose husband was the Prime Minister of Canada. She came in February, 1881, and like all prominent guests (and there were many) was ushered first of all into the library.



WILLIAM CARMAN
Bookkeeper.

It was part of the work of Bookkeeper Carman to keep a lookout downstairs and hold up the gate crashers. Edison afterwards acknowledged Lowrey's foresight in demanding a suitable office and library building as a separate unit in the compound. There the master could seclude himself when thinking out problems, or could take a nap far more comfortably than in the laboratory; for there was a horsehair sofa and fine easy leather chairs, club-fashion. 'Pop' Edison when at Menlo Park was a frequenter of the library, especially after lunch, taking his siesta there if the sofa was not already occupied by our other guest, Mackenzie.

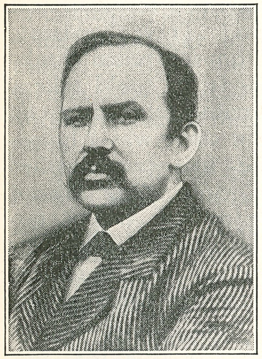
Mackenzie, however, generally took his afternoon nap at 'The Light House,' an inn situated near the stairs leading down to the railroad station. This boarding house and saloon bar was kept by a Scotsman named Davis; so it was but natural that Mackenzie for the sake of 'auld lang syne' should make his headquarters there.

On the ground floor of the office building William Carman kept the books and did other clerical work. It was said that Carman was formerly a pharmacist and followed the drug business up to 1875, after which he obtained a position with

Edison. He also did the work of a purchasing agent in conjunction with his other duties until 1880, when Charles T. Hughes came to us and became our purchasing agent plenipotentiary. Carman had a boy by the name of John Randolph to help him about the place; thus Randolph remained with Edison many years, and at one time, when Edison moved to Orange, acted as a sort of secretary. Carman left Menlo Park in 1883 to enter some other business in New York City.

I have told how in early 1880 Ernest J. Berggren was added to the office staff to assist Carman. Berggren was an intelligent youth whose ambition was to become a bookkeeper, accountant and auditor. Through hard work and attention to business he reached his goal. He became an expert in accounting and was singled out for maintaining the courage of his convictions when called upon in matters of great importance. He remained with Edison for many years, serving him also later at the Goerck Street Edison Machine Works, in Schenectady, and in Orange.

Edison and his secretary at that time had their special desks up on the library floor. Berggren told me once, although we all knew it, that S. L. Griffin, Edison's secretary, was a most agreeable person but one who took things a little too easy, and that, no doubt, was one of the reasons he left soon after things began to hustle at Menlo Park.



STOCKTON L. GRIFFIN
Edison's Secretary—1879.

Sam D. Mott, our patent draftsman, had a desk on the ground floor where the bookkeeper was. There he executed the many patent office drawings required during that period in patent applications. Later Mott was assisted in this work by Edward C. Rowland, also a skilled draftsman. Both these men went on to New York City and continued their work in the Edison headquarters at 65 Fifth Avenue.

When Charles L. Clarke first came to us on February 1, 1880, Edison gave him a desk in the office, where he began computing a wire table and constants just to enable him to shake off that strange feeling one has when entering upon a new situation. It was not long before Clarke was transferred to the laboratory and became one of the regular fellows.

In the restored office and library building at Menlo Park in Dearborn, Henry Ford arranged to reproduce the conditions and aspect of the place to the entire satisfaction of Edison when he last visited us in 1930. The fine office and library furniture is in cherry wood as of old, and as an addition to its historical value, the desks of Edison and his secretary in the library are veneered with wood from the cherry tree that once stood near the little glass house in the Edison compound at Menlo Park, New Jersey.

The very books on the shelves have been selected to correspond with those used by Edison, and none of the volumes is dated subsequent to the years Edison worked here.

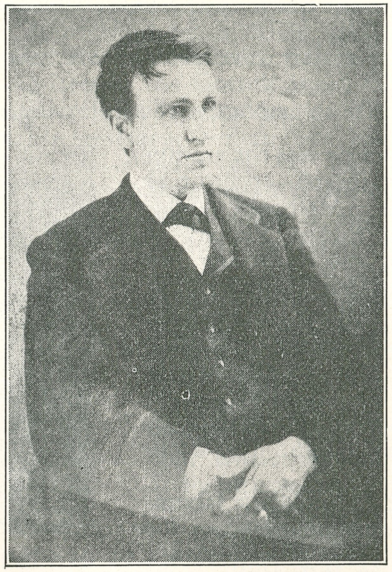
Again I desire to emphasize the following; that:

J. U. Mackenzie was the station master and telegraph operator at Mt. Clemens, Michigan, who taught young Edison the art of telegraphy in 1862. During the past fifty years several others have claimed to have instructed Edison in this art. Mr. Henry Ford once questioned Edison on the subject and he replied: 'There is no foundation for the statement. J. U. Mackenzie taught me telegraphy.'

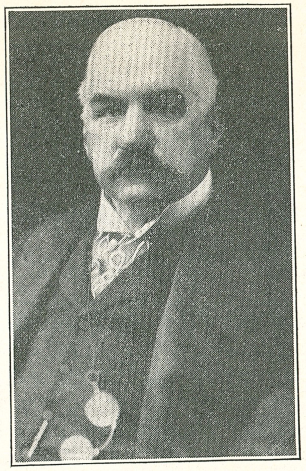
J. U. MACKENZIE

We at the Menlo Park laboratory knew that Mackenzie was the teacher from whom Edison learned to use not only the Morse telegraph key but also the general technicalities of the art in practical business. I have found that as time progresses many pretenders appear claiming to have been an assistant or an associate of Edison at Menlo Park. They want to inspire others with their self importance, and the lack of it makes them overlook the rules of accuracy. Those who really were at Menlo Park and have the least vestige of claiming an assistantship to Edison have their doings and names

documented in the newspapers, magazines or books relating to those days. If their names are not in any of the many Edisonian scriptures that exist, we may be sure that we have a dubious case before us. Edison recalled his men of Menlo Park to the last, and when questioned about others who did a lot of flag fluttering a few years ago, he would answer, 'I don't remember them.'



EDISON, 1879.



J. Pierpont Morgan, of Drexel, Morgan & Company. A warm supporter of Edison and his central station work. (1837-1913)

LXXIV. 'Tunneling' at Menlo Park

WHEN Edison through the influence of G. P. Lowrey received in 1878 the financial backing for starting his great work on the distribution of current for all purposes, he was virtually an employee of the Edison Electric Light Company. While, of course, he was the chief of everything that was going on at Menlo Park and directed all operations, yet he had to give a periodical accounting of how the money was being spent. I remember that Mr. Auerbach, of the firm of Porter, Lowrey, Soren and Stone, would come over to Menlo Park now and then to get these reports from Carman, our bookkeeper.

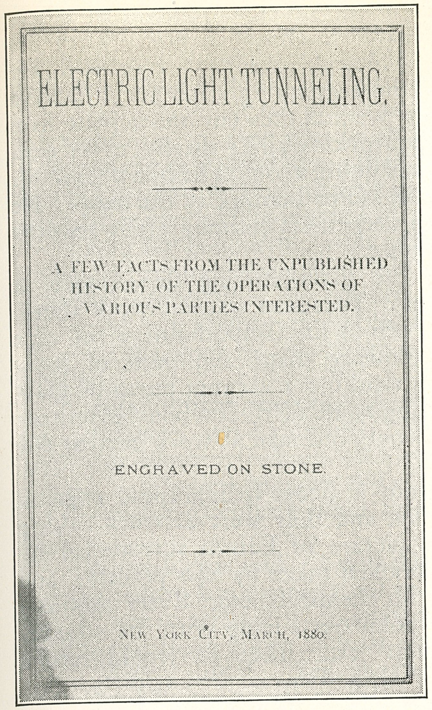
By speaking of this, I wish to impress upon my readers the fact that the laboratory was based upon business principles, and that it was the first one in which *organized research* had its inception on that principle. The idea soon became recognized through the phenomenal success attained by Edison, and manufacturers gradually began to install testing rooms and laboratories in order to cheapen and improve their

products. In 1880 an English newspaper made fun of us by calling our laboratory a factory for turning out inventions, and thought the idea undignified and unscientific. Nevertheless, the systematic methods Edison introduced and his final results had the effect of setting production companies to thinking. We all know what difficulties a lone inventor has to surmount and how often, if successful, he is deprived of the benefits of his labors, especially if he has no financial backing or honest friends.

The circumstances in Edison's life as an inventor, however, were not so dismal; for when he was with the Gold and Stock Company, and the Western Union Telegraph Company, he received more pecuniary benefit than he had expected. While working out inventions for these companies he also received services that a lone inventor without special connections rarely obtains. The protection of business and legal advice was always at his disposal, the more so when he started his great work on a system of domestic lighting, all parts of which had to be invented. The great guardian who always had an eye upon him was Grosvenor P. Lowrey, and when allotted installments of cash ran out and impatient stockholders began to murmur, it was Lowrey that not only assuaged their ire but got further cash for the laboratory. He kept his eye on all Edison did so that the products of his genius would be protected from the wicked ways of the world. In those early days he scrutinized patents and made corrections if necessary or divided one patent into several to render each part more valid. Recognizing the immense value of a new system of lighting for the future, Lowrey and his firm strained every nerve to nurture it.

While the world was still in a furor over Edison's success in the early part of 1880, it became necessary to take certain precautions in the visitors allowed at Menlo Park. Many of these came in good faith, while some, we found later, came for purposes not honorable.

I have already told of the note Edison sent to all employees on February 19, 1880, and I might now say that its purpose was not solely that of a reprimand for the more garrulous boys: its main object was to prevent the imparting of certain information to strangers. That many spies came there was no doubt; well-known men came either in their own name or that of others to decry Edison's triumph. Some came with the desire to spy out all they could and then to copy


ELECTRIC LIGHT TUNNELING.

A FEW FACTS FROM THE UNPUBLISHED HISTORY OF THE OPERATIONS OF VARIOUS PARTIES INTERESTED.

ENGRAVED ON STONE.

NEW YORK CITY, MARCH, 1880.

Front cover of booklet telling of secret service operatives and their investigation of electric lighting.

Edison's lamp, giving it a changed form. I shall come back to the case of one or two later.

In March, 1880, a detective agency summarized their activities in a pamphlet(1) on electric lighting. The title was 'Electric Light Tunneling. A few facts from the unpublished history of the operations of various parties interested. Engraved on stone, New York City, March, 1880.'

The pamphlet shows the 'operatives,' as employees of a detective agency were called in those days, sleuthing about in various places where electric light interests either were in progress or were being handled. Names are mentioned that were known in those days but which are almost forgotten today. What interests us is the report on Edison and his work.

After the 'operative' mentions how he got to Edison without creating suspicion he says, 'He was soon satisfied by my talk that I was perfectly sound, so he called up a tall, six-foot fellow (Upton) and told him to take me and show me everything there was about the institution. Then turning to me, he said, "This gentleman will show you better than I can."

(1) This pamphlet was secured years later by John W. Lieb, senior vice president of the New York Edison Company.

And we started on a tour of the shops. We went in where they were making his dynamo machines at first. They are the most cumbersome, ill-looking things I ever saw for dynamos. They look like those stamping machines they have out in Colorado, or the big punches they cut boiler plate iron with. They appeared to be working along slowly, every man working on his own time and doing about as he had a mind to.

'Then he showed me the lamps burning in the shop. He said they were obliged to keep them burning eight months before they could do anything.

'We then went into the glass-blowing department, a separate building, out back. Two men were at work there. Edison had enlarged the bulb of his lamp about 33 per cent and they were at work blowing them, and parts of these vacuum pumps. Edison is working a vacuum pump of glass entirely. They were putting some of the carbon horseshoes into the lamps. There was only one man at work putting the carbons in (Batchelor).

'From there I went into a photo-lithographic concern that Edison has just got up, and they were at work taking pictures. There was one picture of Edison surrounded by about thirty-five of his workmen taken by this process; and they had a man at work with chemicals, etc. Every now and then my conductor would point out a lamp with the remark, "How nice that is burning!" etc. Then he would turn a little screw to turn the light off or on. He could not regulate it intermediately. It was either all off or all on. I asked him if they could regulate to any intermediate point and he said they could not. "These horseshoes burn very well," he said.

' "Some of them

'Every now and then my conductor would point out a lamp with the remark: "How nice that is burning!" '

burn on an average about 800 hours continuously." My conductor then took me where the dynamo machines were working and showed me the engine which he said was 80 HP-150, I should think, judging from the size of it. He said they had a hundred lamps burning, but I am positive there were not over 50, even if as many as that, everywhere, in the shop and out of it; and to run them he had 3 dynamo machines worked by this engine, those big upright machines of Edison's, that my conductor said had a capacity of 50 lights each.

'I told my conductor, aside of Edison, that my principal object in coming there was to make arrangements to start up a factory and go into the business, and asked him how soon we could get territorial rights, licenses, etc. He replied, "I guess we shall be able to give rights in about five or six months."

'I asked Edison the same question afterwards, aside from my conductor, and he replied, "Well, I don't know. Some time this summer, I think. I leave that to my bankers and others." (Drexel, Morgan & Co. I think he said.)

'I asked particularly what there was to occupy so much time.

'My conductor said, "I will tell you, Mr. Edison is under engagement to his company not to put these lamps before the public, nor to attempt to do anything in a practical way until he has run these lamps at least eight months."

' "Well," said I, "Yes, that looks reasonable."

' "Mr. Edison wants to thoroughly test it and they want it thoroughly tested first," said he.

' "Meanwhile," I proceeded, "does Mr. Edison contemplate bringing out any new form of lamp, this carbon pencil arrangement or anything of that kind?"

' "No, no," said he. "Mr. Edison is going to stick to this horseshoe form that he has invented, and only expects to improve it in the matter of texture of the filament. We are experimenting now with the various kinds of cloth-made paper and looking after the finest and best-textured paper, so to speak, to make these horseshoes of. We expect to put lamps all over the Park here."

'We then went into the place where they bake the horseshoes. There were three small new furnaces not yet working, which proved conclusively that what he said was true, that Edison was still hanging to the horseshoe, and only looking for a better material to make it of. He then expects the lamps

Right to left—George S. Hamlin, Charles Francis Stone, Judge John K. Porter, Grosvenor P. Lowrey, George Wales Soren, son of Judge Porter.

to be perfect. I could see that all their hopes hang upon one thing, the horseshoe . . .'

The operative then sums up by saying that Edison seemed dissatisfied or disappointed and looked as if he had been sick. He thought Edison was all right but was a tool for his bankers, who wanted to make money out of the company.

That there was great excitement and speculation in the district about Wall Street at the time, the following clipping (one out of many) proves:

THE EDISON BOOM. HOW LONG, HOW LONG!!

(Under the above heading, The New York *World* in one of its early issues of January, 1880, runs the following comment):

Kirkland & Milliken, of 47 Williams Street, reported yesterday that speculators are anxious to trade in Edison Electric Light Company stock, and that investors are picking up five and ten share lots. Mr. Laportas, of the firm, said to a *World* reporter that two shares were sold yesterday at $3,500 each, but that lots of ten shares, which are more desirable, are in strong demand and are worth $4,500 to $5,000 a share. One of the largest shareholders, who was offered $700,000 last week for 200 shares, was bid $800,000 cash last night, and says that he will not sell under $1,000,000.

I have never been able to find out who the parties were that employed this detective agency. If I may venture a guess, those interested in gas had something to do with it. It all shows the pitfalls that are laid for an inventor when paramount interests are at stake.

It is thus no wonder that G. P. Lowrey counseled prudence in showing people round and at the same time took precautions without Edison's knowledge for the company's sake. Yes, Lowrey was ever on the watch, and as we approached the busy termination of the work at Menlo Park, the Edison Electric Light Company knew perfectly well which men at the Park were loyal and which were not, even before Edison had any idea of it. It was one of these gumshoed gentlemen whose report on Boehm caused the latter to leave Menlo Park with lightning rapidity. I remember one of this company's shadowers well; his name was Russell. He once got into a jam and was beaten so severely that he had to cover his whole back with a large porous plaster; his nickname after that was 'Porous-plaster Jim.'

I have given all these details in order to show what privileges and protection an inventor enjoys when, like Edison, he conducts organized research for a strong company. He has everything at his disposal and can devote himself, without worry, to his work. If he is successful, he gets his liberal share and has no expense. If Edison had stuck to the stocks received from the Edison companies for his work he would, no doubt, have been the largest sharer in electric lighting interests in the country. But Edison was not after money solely. No! He considered it a means of exchange and in that spirit turned it into new activities, new endeavors and new lines of experiment. It was important that he should do so: otherwise history might have had a different course. He did not wait in leisurely luxury until his electric light shares should grow fat with returns, but from the start took all the money he could raise to place his great achievements

upon a solid commercial foundation under his personal supervision. That was necessary considering the epoch. With him it was push, push, and push again, and with the help of loyal servants the gigantic results of his Menlo Park labors were soon safely set on a manufacturing foundation; in a few years they were fortified to an impregnable strength. Then the time arrived for others to carry his work of expansion further—this, however, only after a decennium. In 1892 the General Electric Company took up his program of expansion and has been developing it ever since.

On October 23, 1880, the *Scientific American* brought out an article on 'Recent Developments in Electric Lighting.' It was mainly devoted to H. S. Maxim and among other things mentioned the following:

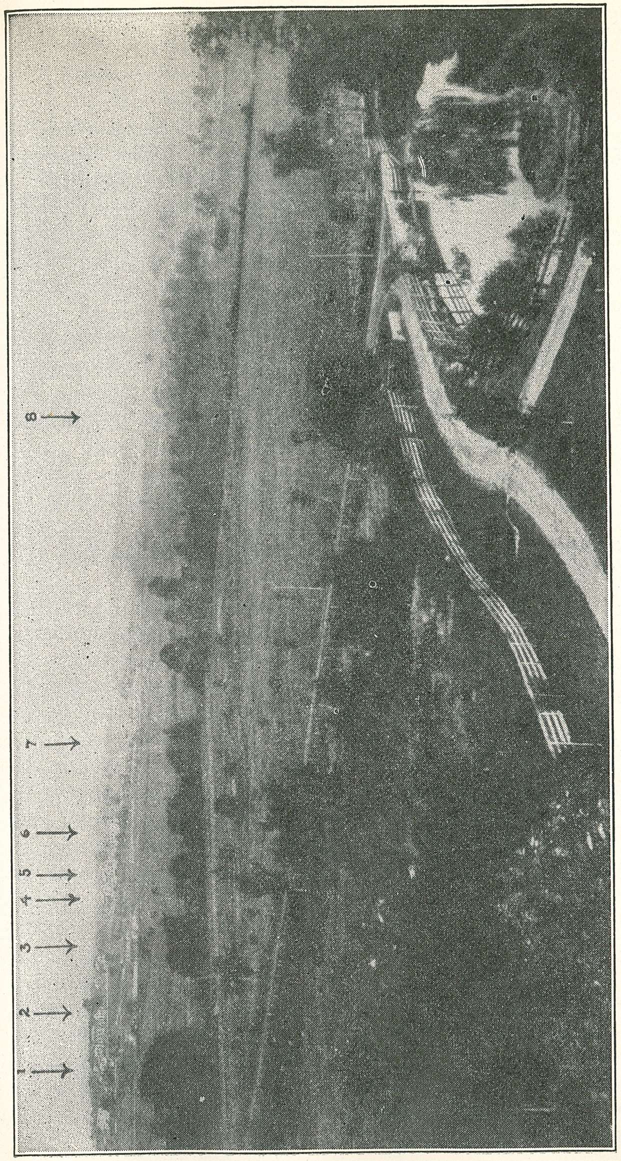
> We also furnish views of Mr. Maxim's incandescent lamp which is now brought to public notice for the first time, although, as we are informed by the inventor, the lamp was made substantially in its present form some three or fours years since. In fact Mr. Maxim claims to be the pioneer in this direction.

Then in a footnote we find—

> The application for a patent on Mr. Maxim's incandescent lamp was filed October 4, 1878.

Here we are confronted again with one of those statements so misleading to a layman public. In the first place, the Maxim patent application of October 4, 1878, which was granted first on August 10, 1880, was solely for the lamp I have shown in Chapter LVI, page 476. It contained a strip of carbon of very low resistance in a container of glass and metal, which proves it would never be of any practical worth for distribution. As for the lamp itself—if I may call it such—it had no life. It was like Swan's, only a discarded experiment—and was now being mentioned again for misleading purposes.

The new lamp that Maxim brought out in October, 1880, is shown on page 612. It is evident to any sane person that it was but a copy of Edison's paper lamp of 1879. The only difference was in shape. Maxim punched his cardboard out in the form of a Maltese cross, while the Edison one was in the form of a horseshoe. In that *Scientific American* article Maxim, however, forgot to inform the journal that his new



Bird's-eye view of Menlo Park showing: (1) Upton's home; (2) Edison laboratory compound; (3) Pennsylvania Railroad station; (4) House where Clarke and Dean lived; (5) Jordan Boarding house; (6) Home of Batchelor and Kruesi; (7) Edison's residence; (8) First lamp factory.

lamp which was 'now brought to public notice for the first time' was the result of the fact that our former glass blower, Ludwig Boehm, had left Edison and had joined Maxim in his New York City shop. Maxim had been at Menlo Park in the summer and Edison had shown everything to him. It came to our attention afterwards that Boehm went more frequently to New York than usual and doubts of his loyalty arose. The matter was looked into and it was found that he visited Maxim's shop, located somewhere around Sixth Avenue, uptown, near some street in the 'thirties.' The result was that Boehm disappeared suddenly from Menlo Park and joined Maxim's force.

A most interesting interview on this subject appeared in the New York *Express* of November 26, 1880. Sawyer gave his opinion of Maxim and Edison:

'Clever operations of electricians. A spicy interview with Professor Sawyer.

'SAWYER ON EDISON AND MAXIM

'A reporter called on Mr. Sawyer at his residence, No. 200 West 42nd Street, and the latter said:

' "I know Mr. Maxim very well, and while he is beyond doubt one of the best mechanical engineers in this country, I have no hesitation in saying that in his last attempt at electric lighting he has made a wholesale appropriation of other people's property." Edison's statement to the same effect has already been published. "But how can he do that?" asked the reporter. "Easily enough. There is no law to prevent any man making, exhibiting, and experimenting with the inventions of others. A dozen men may go to work and do the same thing that Maxim has done. When it comes to doing business and making money out of others' property, then, and then only, can the infringement laws be invoked. In 1877 I was associated with a Mr. Schuyler, and Maxim was employed to reduce my work to practical mechanical shape. I did not like Maxim and was distrustful of him; several times he had the effrontery to claim to others before my face ideas given by me. Finally I was given the option of taking Mr. Maxim in as a joint inventor and sharing equally with him, or a discontinuance of my work. I decided upon the discontinuance plan, and have had nothing to do with Maxim since."

' "I see that Professor Morton and Professor Barker both speak in terms of praise of the Maxim light." "Yes, I have read all that they had to say, and it amounts to very little. After all his effusiveness about Edison, Professor Barker's turning around to Maxim and against Edison puts him in a very bad light.

' "Maxim virtually acknowledged that he was infringing Edison's horseshoe lamp patent, that in his distributing system he was infringing the Sawyer-Man distributing system, and that in forming his carbon loop by submitting it when heated to incandescence by the current to a stream of hydrocarbon vapor, he was infringing the Sawyer-Man patent for that process. You will see that Professors Morton and Barker unite in crediting Maxim with this discovery, but this is probably because they have been misinformed. His carbon is no better preserved in a hydrocarbon vacuum than in the Edison vacuum. What Maxim does is to fill his globes with gasoline vapor and then exhaust. There is only a trace of gas left, and this is soon decomposed, the carbon being deposited on the loop and the inner surface of the globe, and the hydrogen is set free. Thus his lamp almost immediately becomes one sealed in a hydrogen vacuum; and if Edison will fill his globes with hydrogen, and then exhaust, he will have identically the same conditions as Maxim has in his hydrocarbon vacuum. The ideas given out by Professor Barker and others are the more surprising when it is considered that such men should have a sufficient knowledge of chemistry to be able to detect the flaws in the Maxim process as stated by its projectors.

' "I have seen Edison's patent and Maxim's patent. The devices for hermetical sealing of the globe described in Maxim's patent are not used by him, but all the devices shown in Edison's patent are used by Maxim. Maxim is a great adapter, and changing the horseshoe into a double loop to form a letter M is characteristic of the man. But a few years hence he will not be heard of in electric lighting, except as putting his name to the work of others, while I have some confidence that Edison will. Edison's improved generator, I am informed and believe, is a very successful one, and there is altogether too much outcry against him on account of his delays. I have never fancied Edison, but there is one thing that ought to be said about him in this matter of electric lighting: whatever question of priority of invention may

arise, I am satisfied that Edison has never shown a light or any connected appliance that did not originate in his own mind as well; and I have respect for a man that travels on his own merits. If I were in Edison's place, I would put into my lamps carbons of lower resistance, and run them at a higher temperature, for there is where the economy is, and I would not make an exhibition until good and ready. If people will let him alone Edison will do a great deal better than he has done. Maxim is about as shrewd a man as they make nowadays.'' '

Following was Edison's comment on the matter:

'EDISON ON THE MAXIM LAMP

'When asked about the Maxim lamp on exhibition in New York, Mr. Edison said that he had not seen it, but his friends had. He thought it was a clean steal from his lamp. He did not believe in the hydrocarbon vacuum; he smiled at the idea of plugging a vacuum with wax. It would be found, he believed, that the globes were fused at the point.

' ''I do not worry about them, or a hundred like them,'' he said; ''I always expected them, and there will be more of them. The lamp is to a system of electric lighting what a gas burner is to a gas works. They know just what they are about. It is simply a stockjobbing operation to float electric arc stock.''

' ''What's in a name?''

' ''But there are reputable names in the company.''

' ''All the better for the other fellows. What does a capitalist know when a man shows him a patent with a full-blown picture of an electric lamp on it? The claim may be for a stopcock or a piece of wax, but the whole lamp is in the drawing and the capitalist thinks the fellow has a patent for everything in the picture. Oh, reputable names are just the thing. They said there—and it was published somewhere—that they were not ready to take orders for incandescent lamps, they had so much to do on the other lamps.''

' ''If it is a copy of your lamp, how did they get it?''

' ''Well, my lamp is no secret. Mr. Maxim came here himself and spent an entire day from morning until late at night, looking over the whole place. Then he got hold of one of my glass blowers, and that's the whole thing in a nutshell.'' '

About this same time, that is, October 29, 1880, J. W. Swan gave a lecture before his home town society, the Literary and Philosophical Society of Newcastle-on-the-Tyne, England, and showed a new lamp. This lamp was not of the carbon rod or cylinder variety but like the Edison lamp of the previous year. As Swan constructed it with a filamentary carbon, it was, a direct infringement of Edison's patent.

You have read what Sawyer said about Edison and his lamp, and here I wish to mention that of all contemporary workers of those early days (when efforts were being made to use a stick, pencil or cylinder of carbon as a light-giving element in a lamp), the work of Sawyer out-paralleled that of the others. In 1878 he made the acquaintance of a Brooklyn lawyer by the name of Albon Man who furnished the money so that Sawyer could continue his work. They opened a shop at 43 Center Street, New York City, and it was there that he made the lamp shown on page 625.

It was Sawyer who discovered the process of treating carbon in gasoline vapor which deposited a layer of graphitic carbon on the heated carbon element. Sawyer also tried, like some Russian scientists before him, to employ nitrogen gas in his lamp, but did not have any success.

The Sawyer-Man system with a pencil of carbon lamp was first demonstrated in New York City on October 29, 1878, by the Electro-Dynamic Light Company. We know that Swan (page 468), exhibited his cylinder of carbon lamp first on December 19, 1878. Sawyer's lamp was described and illustrated in the *Scientific American* on December 7, 1878.

In the case of the incandescent lamp we see repeated the same age old process of invention and imitation. The remote genesis of its possibilities was shown by such men as Davy, De La Rive, Grove and others. They were followed by others who with a practical turn of mind saw that such a lamp would fill a pressing need of mankind. A flock of men attempted to solve its practical solution and although they worked enthusiastically, they possessed no tactics; they kept adhering to the processes they inherited from their predecessors and so ran constantly in the old rut. Failure followed failure. Suddenly a prophet appeared—Edison—who by the sheer exercise of original thought, opened a new field and a new direction for investigation.

Joseph Henry said: 'The man of true genius never lives before his time, he never undertakes impossibilities, and always embarks on his enterprise at the suitable place and

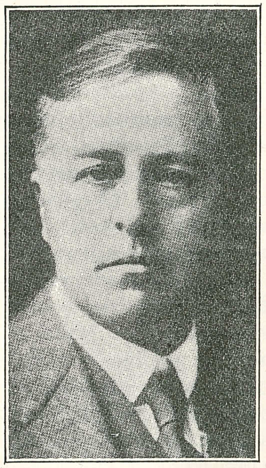
period. Though he may catch a glimpse of the coming light as it gildes the mountain top long before it has reached the eyes of his contemporaries, and he may hazard a prediction as to the future, he acts with the present.'

Thus Edison makes the lamp the world was waiting for: Instantly those who have never hitherto succeeded in discovering the correct method rush helter-skelter and take up the new principles. They succeed in making a lamp after hundreds of Edison lamps have been shown to the public. They call it their own and boast about having done it years before. Enlightened men are amazed at such allusions; it is difficult for them to understand the complexities of such psychological caprices.

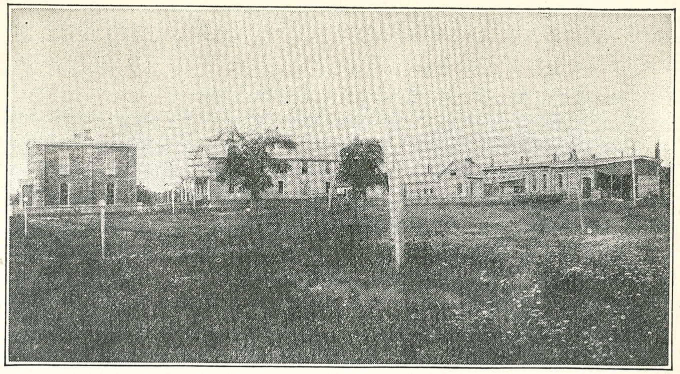
* * *

Generations have passed since those days and Edison and his work still live on while his imitators are forgotten.

Only a little while ago, Sir James Jeans in his presidential address before the British Association for the Advancement of Science, in discussing the rich gifts that *Science* bestows upon mankind, said, 'The scientific work of one man, Edison, produced an economic value estimated at £3,000,000,000!'



Sir James Jeans, president of the British Association for the Advancement of Science. In his presidential address he declared that Edison alone contributed £3,000,000,000 to world economics through his inventions and scientific discoveries.



View of Menlo Park photographed during 1880.

LXXV. Activities at Menlo Park 1880

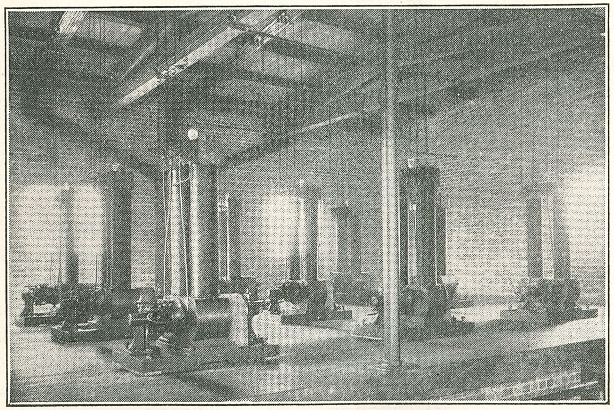
FROM an historical point of view Edison's first demonstration of his newly created system of domestic illumination was the thriller of the period. As we know, this first exhibition took place in 1879 and 1880 and there were only about one hundred incandescent lamps in action. However, one hundred such lamps, new to the world, produced a gigantic effect; for they marked a new epoch in the world's history and in the annals of electricity and proved that at last that intangible force had been harnessed by Edison and would serve mankind in the future. For many years others before Edison had been hunting to attain something similar; they failed, for they were all working in a wrong direction and all had a false idea of the qualifications of an incandescent lamp.

Edison had reached the loftiest peak in his fame and the results of his efforts produced an instantaneous shake-up among scientists and laymen. As in 1849, when gold was discovered in California, there was a rush and scramble into the domains of practical electricity which had heretofore been ignored, because so little was known about it. Edison's work and his conception of a central station that was to supply current to all, brought a host of men out of lethargy who soon created a hustling world and the gradual start of

the machine age. These all began to follow the path that Edison had opened and had proved to be the one that would lead to results. Men began to get confidence in themselves and dared to attack problems that were formerly considered the exclusive right of but a few to handle. In short, Edison's first exhibition at Menlo Park in 1879-1880 marked the start of an age when men more than ever tried to convert the wonders of science to practical purposes. The immenseness of Edison's results opened a new field full of inspiration and possibilities. Such was the effect produced upon all who in 1879-1880 came to Menlo Park, whence the news was heralded to the world.

The exhibition given by Edison during the latter part of 1880 and for some months in 1881 was a last showing that his system was commercially sound and feasible in every respect. He was going to satisfy not only his financial backers but outside engineers too by an extensive test with an installation comprising about six hundred incandescent lamps. The bamboo lamps were to be shown in action; for the first Edison lamp factory down at another end of Menlo Park was already beginning to get ready to turn out its product.

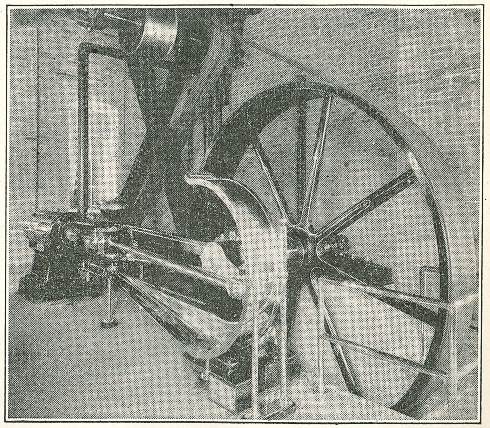
Kruesi received orders from Edison to build generators. Edison had decided to make ten generators to supply the current and an extra one to be used as an exciter. The Edison dynamos were improved; instead of wooden bedplates iron



Generators in 2nd central power station at Menlo Park—1880.

ones were used; to take the place of vertical standards for brush-holders, the rocker type found its inception. This was a great improvement, permitting us now to regulate, or shift, the dynamo brushes when necessary. Another novel addition was a dynamo switchboard with a plug switch that was placed on the front of the field magnet yoke of the dynamo. The iron wire core of the armature was changed for a most efficient laminated one of very thin soft Japanned sheet-iron disks. The commutator bars were insulated with mica, and other improvements were made in the winding of the armature coils. Some of these generators, after the exhibitions had ceased, were employed in equipping the Edison headquarters in New York City and a number of the first plants here and abroad. The machine shop was kept busy during the summer and autumn of 1880, since not only had the generators to be made but also many things for the new lamp works down by the Pennsylvania Railroad tracks. An addition was built in the back of the engine room to house the electric generators which were to be driven by the Brown steam engine installed in the latter part of 1878. This engine was rated nominally at 80 horsepower.

Our steam boiler was made by Babcock and Wilcox and was of the water-tube type with about 853 square feet of heating surface and 26½ of grate surface. This same boiler is still performing active service at the Edison laboratory in Dearborn and supplies power to the Brown engine, built by Charles H. Brown, of Fitchburg, Massachusetts, more than a half century ago. From the large flywheel of this engine a 16½-inch belt conveyed the



Brown steam engine in machine shop at Dearborn.

power to a shaft in the basement of the dynamo house adjoining the engine room. The eleven dynamos were driven by the pulleys and belts from the basement, the belts passing through openings in the floor where each dynamo stood. A well by the side of the machine house supplied the steam boiler with water. It happened, as I have already mentioned in another chapter, that when we were working with a full load, there was not sufficient water from this source; Edison was forced to lay a pipe line and pump water from a stream that passed an abandoned copper mine some distance from the laboratory.

In the summer and autumn of 1880 Menlo Park was humming with activity, and that was the period when Edison employed the most men, many of whom held their jobs for a few months or more. I mention this fact because one reads now and then exaggerated accounts of the large number of men at the laboratory and machine shop. The truth is that we had at the most about seventy-five men. I do not include here the help that was engaged at the lamp works, which had nothing to do directly with the laboratory. The expenses of the laboratory were paid by the Edison Electric Light Company organized in 1878 while those of the new starting lamp works were paid by Edison, Batchelor, Upton and Johnson, who were all partners in this exclusive new undertaking. Of course, Edison's share and interest in these works predominated over the combined interests of his partners.

In the lamp works, Holzer, assisted by Hipple, was busy instructing a large number of young men in the relatively new art of blowing glass. It was the first school of its kind in America—yes, in the world. When we consider the speed with which this practical master of the glass-blowing art converted raw recruits from round Menlo Park into good workmen, it is not far-fetched to designate William Holzer as the father of commercial production of glass parts for incandescent electric lamps.

Edison's principal assistants in the laboratory—Batchelor and Upton—devoted nearly all their time to getting the departments of the lamp works in order. Their signal achievements in the processes of commercial evolution cannot be overestimated. Honest John Kruesi contributed his part in making such appliances and utensils as were found necessary to start the departments Batchelor and Upton were adjusting. Johnson, of course, had nothing to do with these activities;

he was an outside man for Edison—a sort of company organizer, publicity man and propagandist who had already done good work in this capacity for the phonograph, the carbon telephone transmitter and the chalk telephone receiver, and about this time was starting to work on the Edison electric light system for England. He assisted Edison in introducing his inventions and creations after they were in practical shape. I do not wish to infer that he dominated; Edison, through the assistance of his best wisher, Grosvenor P. Lowrey, was the real starter of the Edison Electric Light Company. That was the crowning act in Edison's life. According to destiny Lowrey's preliminary assistance to Edison and the results the latter accomplished created the events that brought all those old Edison workmen into the organization.

GROSVENOR P. LOWREY

One of my first chapters stated that Grosvenor P. Lowrey was my chief before I came to Edison. When I turn back to those days, I am conscious of the noble character he exhibited and the great role he played in the history of electric lighting. Frank L. Pope in writing of Lowrey said:

'One of the most important services which Mr. Lowrey has ever performed was in furnishing and procuring the necessary financial backing for Thomas A. Edison, in bringing out and perfecting his system of incandescent lighting. With characteristic pertinacity, Mr. Lowrey stood by the inventor through thick and thin, in spite of doubt, discouragement and ridicule, until at last success crowned his efforts. In all the litigation which has resulted from the widespread infringements of the Edison patent, Mr. Lowrey has ever borne the burden and heat of the day, and perhaps in no other field has he so personally distinguished himself as in the successful advocacy of the claims of Edison to the invention of the incandescent lamp and everything thereunto appertaining.

'In private life Mr. Lowrey was esteemed and beloved; it is not too much to say, even by his enemies. Let him strike as hard as he would—and no man could strike harder, in a

cause which he believed to be just—it was impossible to feel a shadow of resentment towards the man himself. There was a transparent honesty of purpose, a polished keenness of repartee and an exuberance of genial and quiet humor that was impossible to be resisted. As an after-dinner speaker, those who knew him best, regarded him as without a peer. His genial fancy roamed untrammeled from grave to gay, from lively to severe; a more charming companion in hours of recreation, it is impossible to imagine.'

Yes, Lowrey was all that and more.

Batchelor and Upton were assisted in their work by many of the men who were formerly at the laboratory and had been transferred to the lamp works. With every new project the high council, that is, Edison, Batchelor and Upton, always met at the laboratory, and if anything in Kruesi's line of work was involved he, of course, joined them. Those who remained at the laboratory had much to do in various ways: trial bamboo lamps had to be tested for resistance, for voltage at 16 candles and for endurance, and in addition I was conducting experiments with the electrolytic meter.

There was another activity going on at Menlo Park which I have not as yet mentioned. This was the experimental work of laying underground conductors for the final demonstration. Edison is the father of underground conductors for conveying current for light, heat and power. That is evident, since he invented the new system, the new lamp and the new kind of efficient dynamo and now he wanted to provide an efficient and safe means through which the current could be transported. The only way, he said, was underground. This method he tried first at Menlo Park in a cheap experimental project without any intention of permanency. The first underground system for incandescent lighting forms an interesting story in itself, and the man to whom Edison intrusted this work was Wilson S. Howell.

WILLIAM J. HAMMER

I have already mentioned Wilson S. Howell as having come to us at Menlo Park during December, 1879. He was the lad who said he had studied in the 'little college on the hill at Menlo Park.' We knew well that the Edison laboratory was the Alma Mater of other men also whose names are indelibly written on the scroll of incandescent lighting—patient and willing men who remained with Edison not only through the trying days at Menlo Park, but on into the pioneering introduction of his light system after laboratory days were finished.

The Menlo Park disciples of Edison, of whom there were but a few, were the first pioneers of incandescent lighting. When the work at the laboratory was finished, Edison sent these trusted men of his out into the world to raise his standard; some continued their work in this country and others went to foreign places to do their share. They were all emissaries of their great chief. They also assisted in drilling the recruits that came flocking to the new cause. Their recompense was the great moral victory of seeing the Edison system, which they had helped to launch, become deeply and universally rooted in a service to mankind beyond all expectation. Theirs is the satisfaction of having served their master honestly, and as honest servants having always remained true to his tenets.

Although Edison had many brilliant achievements to his credit both before the years at Menlo Park and afterward, his universal system of current distribution, the practical incandescent lamp and the commercial current generator outshine all the others. The entire world showed its appreciation when it celebrated Light's Golden Jubilee in Edison's honor on the 50th anniversary of the birth of the incandescent lamp on October 21, 1929, and when The Edison Institute and Museum at Dearborn were dedicated.

In this system Edison had to work out many details and surmount difficulties that neither he nor any other ever before had been called upon to meet. Edison had set up a world of new apparatus that never before had been visioned. Among the things was a system of conductors which lead from the generator to the places of consumption. This included many kinds of insulated wires, cables, etc., necessary in the erection of central stations. Edison created this vast industry because his system required it. He had to obtain some practical pioneer experience, which later terminated in the underground electric tubes that were used in the early days by the first Edison companies. Experience is a great master

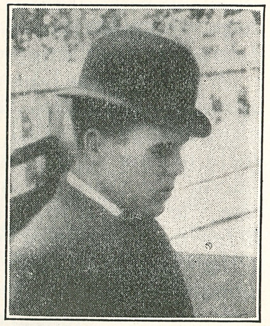
and when combined with patience and common sense always leads to success.

Can one ever forget the heroic patience and labor required for the laying of the first successful Atlantic telegraph cable? The failures in 1857, 1858 and 1865, together with the great sacrifice of money, did not discourage those undaunted and determined men. They had to acquire the art of making a cable, of laying it and of testing it. All this had to be done through original experiment alone, and so after they had lost hundreds of miles of cable during former attempts, they succeeded in 1866 in laying the first successful one to connect the old and the new worlds.

So it was in electric lighting by incandescence: Edison, through sheer persistence, worked out detail after detail until success was assured. In our first demonstration of 1879-1880 we used overhead conductors on poles, although Edison had long before said his system would use underground conductors, especially in cities. He had made up his mind to give another demonstration—a more complete one with underground conductors in conjunction with the new bamboo filament lamp. Instead of one hundred lamps, he proposed to light six hundred lamps with current from a new battery of dynamos. He was going to make a final and commercial test of all so that his financial backers would be thoroughly satisfied. And then the work of commercially introducing his system would follow.

Kruesi soon got the order to build the necessary dynamos with certain improvements; at the same time he was requested to take H. A. Campbell, the carpenter, and build a rough wooden annex to the lower north side of the machine shop to house the generators.

The underground conductors were intrusted to Howell. Here was something new and not to be found in textbooks or scientific journals. Of course, we knew that India rubber was a good insulator used successfully with submarine cables, but there existed



FRANCIS JEHL in 1880.

no precedent for its use in lighting by incandescence. The commercial element had to be considered too; copper conductors for electric lighting were bulky, whereas the submarine cable did not require a large cross section of this conductor. Wood, we had always been taught, was a good insulator, and Edison's first idea was to use wooden troughs and lay the bare conductors in them. These troughs were about the same as were later used, under the name of mouldings, for the wiring of buildings. In those Menlo Park experiments Edison did not wish to lay any network of conductors for permanent use or for long-time insulation. His idea was that if the insulation held out for a few months' demonstration, it was all he desired, because he did not care to risk too much money on it.

'If the leakage,' he said, 'is the equivalent of the current used by only a few lamps, it does not matter.' The manner in which Edison proceeded provided the best school for our study, because we knew nothing of insulation for underground conductors. Who would have thought that a small leak would grow larger and larger, or that decomposition, electrolysis and other actions would set in when a high tension and a heavy current were being employed? Questions of this nature had never before arisen. True, the subject was later studied thoroughly and became a specialty in electrical engineering. Our ignorance no doubt seems ridiculous now because we have learned those facts long ago in school; one must not forget that what he learned was deduced from gropings of pioneers.

The wooden mouldings with the bare copper conductors were buried under six inches of earth and Howell asked me to test the line. The test showed the insulation to be good and it was so reported to Edison. 'All right,' said he smiling, 'but wait until we get a good rain; for the ground is very dry now.' We did get a soaking rain in a few days and when I tested again, there proved to be a dead short. 'Get me a key and sounder with a Daniell's cell,' requested Edison. The cell and instruments were connected between the lines and Edison found that the sounder worked as well as any in a telegraph office, so low was the resistance between the wires. From that time the preliminary test was always made with the telegraph sounder, and if that did not work, was continued with the Wheatstone bridge. The sounder and key with which the first line testings were made in those days may

now be seen in the restored Edison laboratory at Dearborn.(1)

Edison now requested Howell to have everything dug up, the covers taken off the wooden troughs and coal tar poured over the wires. This done, it soon developed that the leakage was as bad as ever. Dr. Haid tested the coal tar and found it so acid as to cause the prohibitive leaks. Another experiment consisted of filling the grooves in the wooden moulding where the conductors were with a plastic compound of powdered slate and a binder. Again the insulation failed. Edison next had Howell spend two weeks in the library reading all he could find on the subject of insulation and insulating materials, such as resins, gums, oil. If anything was to be found in foreign books, Dr. Moses would translate it for him.

The system of conductors that was employed in the Menlo Park demonstration was the simple two-wire one without feeders. Edison had long before that time made use of feeders in his system, their first practical application having been on the steamship *Columbia*, which sailed from New York in May, 1880. In his patent No. 239,147, the specification of which he signed July 31, 1880, he set down the entire subject in a terse manner. The drawing that accompanies the patent gives a clear diagrammatic idea of the basic Edison feeder system, which ever since has been employed in central station operation. Edison omitted the feeders at Menlo Park simply to save expense and because the whole was but a temporary arrangement. In the second demonstration Edison had the greater part of the nearly six hundred lamps distributed about in the fields around Menlo Park, creating imaginary streets, and he did not consider it necessary to lay feeders for this. The dwelling near the laboratory had all the tension that was necessary.

Howell recalls his experience with the laying of the first underground conductors for incandescent lighting as follows: 'The question of underground wires was vital to the success of the Edison system in large cities. Nothing had been done towards the successful laying of wires under city streets and it was necessary to do a considerable amount of experimentation to determine a practical method of insulation. Mr. Edison planned an underground system running under the streets of Menlo Park lighting about six hundred lamps in the streets and dwellings. I remember one pair of cables which started out to light a circuit southward towards Mr.

(1) See picture at bottom of page 32 Volume One.

Carman's house. It consisted of two cables, each having twenty-five No. 10 B. W. G. copper wires. After running a hundred feet or more, one or two wires were dropped from each cable and so the cable was tapered until at the end of the line near Mr. Carman's house it consisted of only one No. 10 wire.

'How to insulate these wires was a knotty problem. Mr. Edison sent me to his library and instructed me to read up on the subject of insulation, offering the services of Dr. Moses to translate any German or French authorities which I wished to consult. After two weeks' search I came out of the library with a list of materials which we might try. I was given *carte blanche* to order these from McKesson & Robbins and within ten days I had Dr. Moses' laboratory entirely taken up with small kettles in which I boiled a variety of insulating compounds. The smoke and stench drove Dr. Moses out.'

I may here interrupt Howell's narrative to say that not only did the stench drive out Dr. Moses, but created a most disagreeable situation for us all.

Howell continues: 'The results of this stew were used to impregnate cloth strips, which were wound spirally upon No. 10 B. W. G. wires one hundred feet in length. Each experimental cable was coiled into a barrel of salt water and tested continually for leaks. Of course, there were many failures, the partial successes pointing the direction for better trials. These experiments resulted in our adopting refined Trinidad asphaltum boiled in oxidized linseed oil with paraffin and a little beeswax as the insulating compound to cover the bare wire cables, which had been previously laid alongside of trenches throughout the streets of this little Jersey village. Barrels of linseed oil, bales of cheap muslin and several tons of the asphaltum were hauled in, two 50-gallon iron kettles were mounted on bricks, and the mixing operation was soon progressing in a big way. Through the pot in which this compound was boiled, we ran strips of muslin about 2½ inches wide. These strips were wound into balls and wrapped upon the cables. Up from the ground came the wires once more, suspended on wooden sawhorses above the earth. After the man who served these tapes upon the cables had progressed about six feet, he was followed by another man serving another tape in the opposite direction, and he in turn by a third man serving a third tape upon the

cable in the direction of the first winding. After the cables were all covered with this compound and buried, the resistance to the earth was found to be sufficiently high for our purpose. I remember the first circuit which was completely ready for lighting ran from the machine shop to the Pennsylvania Railroad, branching north and south along the track. I had informed Mr. Edison that afternoon that the circuit was ready to light, but was told not to turn the light on until he gave the word. This happened to be the night of the election for President of the United States and Mr. Edison announced that I should not light this circuit unless Garfield was elected. That night in the upper story of the Edison office a group of kindred spirits gathered about a table at which presided Mr. Edward H. Johnson at the key operated upon a loop in one of the Western Union lines passing through Menlo Park which carried the press dispatches to the New York papers. As the news came over the wire of the result of the election in distant states, a tally was kept and as soon as Mr. Edison saw that there was a safe majority for Mr. Garfield, I was ordered to turn the light on the circuit along the track.'

Steam had been kept up so that it was an easy matter to start the machinery and turn on the current. The long row of brightly gleaming bamboo lamps glittered all the way from the new dynamo annex along Christie Street, past Edison's home and down along the railroad tracks. It was a fitting salute for the new President of the United States. This temporary system of underground conductors maintained its insulation throughout the winter of 1880-1881 and was in fair working order when Edison abandoned the demonstration in 1881. He had shown the feasibility of operating underground conductors for incandescent lighting circuits carrying great quantities of current, in fact the greatest up to that period.

Edison with his keen perception was already well aware of the erratic disposition of electric tension, as he had gained experience in its freakishness in his early operating days. And during the years when he conducted his experiments in all phases of telegraphy, tension and insulation were constant factors with which he had to deal. In one of his earliest patents on the electric light (1879) he proposed to construct underground conductors in which the copper was placed in an iron tube and insulated with asphaltum. In fact, the same idea was carried out in the world's first commercial central station. We know that these electric tubes gave excellent service for a generation or so. His sole object in making several trials with wire underneath the ground in 1880 was to seek the most inexpensive method, because he did not care to waste money for insulation that was only intended for a temporary purpose. He was seeking a compromise and was willing to pay a reasonable price in the form of leakage. The trials that were made therefore can only be considered steps in the course of investigations to determine the cheapest way of laying underground conductors to be used for only a short time.

Howell laid some seven or eight miles of these conductors and was assisted in the carpentry work of laying the mouldings and placing the lamp-posts by H. A. Campbell, our carpenter, who had built the frame annex to the machine shop where the eleven Edison electric generators were placed that constituted the temporary central station for supplying current for Menlo Park's second demonstration, in 1880-1881. Now, more than half a century since, Howell has written me a letter in which he refers to the successful laying of the underground cable in Menlo Park in 1880.

'Yes,' he writes, 'I did it, yes! With my hands, *not* with my *thinker*. I was proud of what I did. Mr. Edison was pleased. We were all happy and it worked as long as needed. Mr. Edison rewarded me handsomely. Other than that I never received a cent from him—no salary. This same compound was used for many years afterward by Mr. Kruesi in the Edison electric underground tubes of the Edison system.

'Edison's mind, and his alone, conceived all that came out of his laboratory, but he had no more than two hands and but limited time to conquer all the details involved in completion of his plans; so he looked to us for manual assistance. In some cases he would put into the hands of some one of his assistants the working out of a scheme or he would ask all of us to help him find certain results from a combination which he would describe to us in words and sketches.'

I have stated the same opinion several times in these reminiscences. Whether it was scientist, mathematician, chemist, engineer, experimenter or mechanic, it was always 'Edison's mind and his alone' that guided the successful execution of everything done at Menlo Park. He was the master mind that conceived and directed all operations, and

it was amazing with what *savoir-faire* and calm he set things in motion.

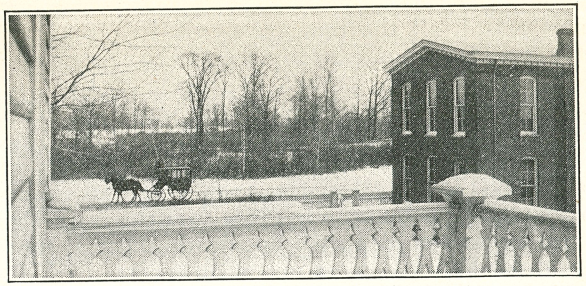
Not only was Howell's insulating substance used in the manufacture of the Edison underground tube conductor at Washington Street, New York, and at the Brooklyn Edison Tube Factories, but it is used today in making the insulating tape that is so universally employed. Yes, the tape that you can buy in almost any store today had its origin at Menlo Park.

I remember well when I was sent to Europe in 1882, brother electricians in the employ of arc light companies would often beg us to give them some of the Edison insulating tape for splices in their lines. The way *they* insulated their wire connections was to take thin sheet rubber and wrap it over the bare wire. To hold it they used cord or thread and that not only took much time but often would not hold. Simple as it is, the Edison tape was, and still is, a godsend to the electrical business; it is used in many ways outside the profession.

A celebrated French scientist was so enraptured when first he saw Edison insulating tape that he exclaimed: 'What a marvelous mind and vision must that American have. He not only created a comprehensive system of distributing electricity in a commercial manner, but made an efficient generator, a new, cheap and simple lamp, a meter; in fact, every piece of apparatus necessary, and last but not least, the handy humble insulating tape.'

R. W. Shenton, editor of *Light*(2), has aptly said: 'Thomas A. Edison held our present electrical industry in the palm of his hand, even as Faraday before him balanced its nucleus on the tip of his finger. Invention is the very apex of the inverted cone that widens out into an industry.'

(2)Published by the General Electric Company.



View from balcony of restored laboratory.

LXXVI. Second Demonstration at Menlo Park

IN THIS second demonstration Edison divided the whole territory about Menlo Park into imaginary streets and lined them with lamp-posts. The posts out in the fields were of a simple nature, plain square ones painted white and with clear round glass globes that protected the incandescent lamps. About the laboratory and the streets that led to the Jordan boarding house, Edison's residence and the stairs by the railroad station were the more pretentious ones, such as have already been described in the account of the first demonstration of 1879-80. The whole aspect of Menlo Park was grand and imposing from the balcony of the laboratory; on a clear sunny day the white lamp-posts with their glass globes scintillated in the sunshine and at night when the electric lights were in operation, the place seemed like dreamland. One writer, calling Edison 'The Enchanter,' said nothing could be more beautiful than an evening view of Menlo Park and Edison's fairyland of lights.

The illumination is over the entire track, and thousands of lights break forth simultaneously to delight the beholder. As the trains from Philadelphia approach Menlo, passengers on the southern side of the cars are the first to see the lights ahead. As the road curves they disappear, soon to burst again into view, however, in a magician's blaze of electricity made subservient to the needs of man. The contemplative mind loses itself in awed amazement. When the famous spot

is being passed, all the passengers rush to the Menlo side, and the excitement only ceases when the last lights disappear as the train dashes on through Rahway.

It was really a spectacle, especially when the fields were blanketed with snow and the radiant glow of the lamps was reflected from nature's white mantle like millions of tiny dancing stars. It was all so new, such a contrast to the sizzling, fluctuating gas burner—in those days the Auer Welsbach gas mantle was not yet born. Such enthusiasm as the public expressed for Edison's great invention repeats itself only in radical and immediate change periods of great importance.

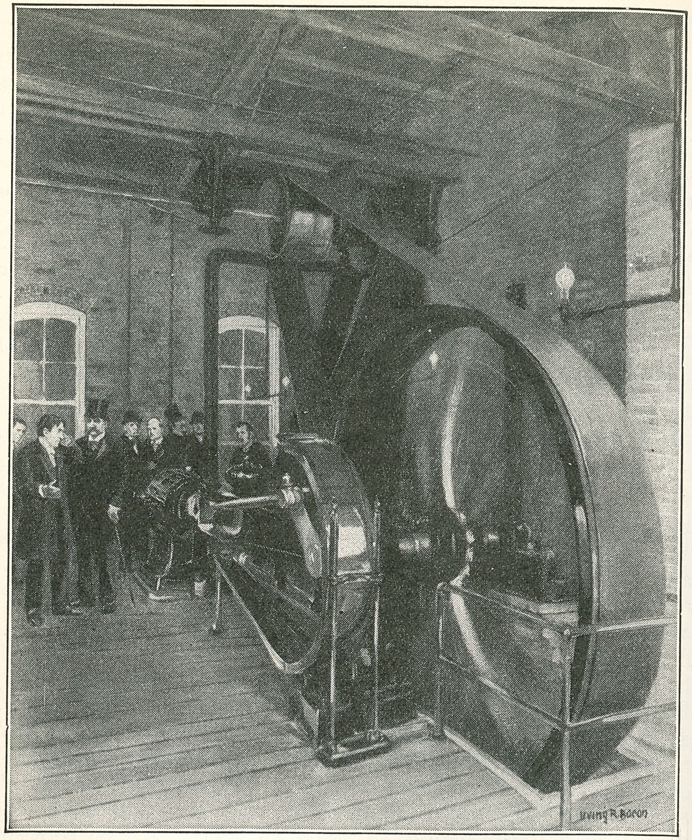
Illumination by gas even at that time was in a pioneer state and for years no general improvement appeared. Then of a sudden and all within one year's time Edison showed the public a new and ideal light having advantages that verged on the fantastic. Yet all was real and tangible and—so beautifully simple. A great universal problem had been solved similar to that which Henry Ford solved with his Model T automobile.

While the many details were being worked out, Edison was also making experiments of which but few knew. I refer to his work on the gas generator to be used for steam generation in the boilers. Outside the boiler house, facing the east, Edison built what to all appearances was a furnace. This furnace was constructed differently from a furnace for making illuminating gas. In fact, Edison's researches on this subject were in a different direction. In the making of gas for illuminating purposes, the fuel used is distilled; that is, the volatile parts are driven off while coke remains behind. In the making of gas for purely heating purposes, as in the gas generator that Edison had built, nothing remains behind but ashes. Such a gas generator is not a furnace in the ordinary sense of the word, since the object is to produce carbonic oxide gas and not carbonic acid gas from the fuel. In this kind of gas generator it is of vital importance to keep the fire at high temperature to accelerate the chemical and physical reactions resulting from combination of the fuel with the air. Not partial but complete combustion is the principle on which gas generators work in converting fuel into gas. In those days this kind of gas generator was not as yet well known or being applied in America, while in Europe its development and use were making rapid strides. Ever since William and Frederick Siemens, in 1860, made their epochal invention of

what is known as the 'regenerator,' the gas generator and the special furnaces used with it have developed into an important industrial science.

As for the experiments made by Edison with the gas generator, after several trials they were discontinued for various reasons. Edison concluded that the gas generator was a great advance and possessed advantages for certain kinds of industries, especially pottery and metallurgical work. As for its use with a steam boiler, he thought the time not yet ripe because there were still many direct improvements to be made in steam boiler operation and steam engines. In the fire box of the boiler you have a specially good generator of heat, only it must be used economically. What's 120 pounds of steam pressure? Nothing! Some day that pressure will be raised so high as to give you the shakes. Look at these steam engines, they are just eating, not chewing, the steam and blowing it away. Look at the heat that passes up the chimney. Everywhere heat escapes without doing work. In this way Edison often discussed the subject of steam boilers and engines with Upton, our mathematician and physicist. Upton had ransacked the books in the library and he was often seen with volumes of the *Dingler's Polytechnisches Journal*, *Engineering*, and like works. As Edison always wanted to know what had been done before in this or that line, Upton saved himself lots of time by studying up the subject and then acquainting Edison with the facts. Edison liked and respected Upton, for the latter had acquired a brilliantly profound theoretical store of knowledge. And under Edison's guidance he soon gained the necessary experience to make theory and practice meet. It was always edifying to listen to their arguments, and often a group of us would gather round and drink in every word that was spoken. Reasonings and sparrings between Edison and Upton often led to new experiments in which perhaps Batchelor's deft fingers or Kruesi's machine shop knowledge took part.

Upton was Edison's chief theoretical assistant, the special man with whom he discussed theory, scientific fact, law and axiom. Others sharing in this esoteric favor were friendly college professors who came to Menlo Park now and then to see how Edison was progressing. Usually a free and easy conference took place and, of course, the subject related to the work we were doing. One must not imagine that on these occasions Edison was the quiet, unassuming man he is some-



Artist's conception of scene in machine shop at demonstration, showing Edison explaining steam engine to J. P. Morgan of the New York group.

times pictured; on the contrary, he would take part in arguments with the zeal that only conviction can generate. He seemed doubly alive; there was nothing he relished more than a friendly disputation on a subject on which the theorists sometimes differed from him. In these wrangles Upton, when it was necessary, assisted by stating the case and explaining Edison's ideas in a way that was more agreeable to the professors.

In the battle of criticism and vicious negation that followed, it was Upton too that carried the skirmishes to a successful and convincing issue. The mathematical computation of network potential problems was likewise his. Calculations of these particular problems found their practical birth at Menlo Park, where the Edison system made them necessary. It was Upton, therefore, that put Kirchoff's and other laws relating to a network of linear conductors into practical form. And so as one of Edison's principal assistants he did the figuring in the scientific creation work that Edison launched, and Batchelor and Kruesi followed with their part—putting the results into tangible form for experimental purposes.

Of course, Batchelor was always considered Edison's principal assistant and that, no doubt, was due to the years of friendly and loyal association that existed between the two. If anyone should ask me who was Edison's principal assistant, I should answer, 'Edison himself.' There was no principal assistant, if the question implies a better man who did more than another. Edison had three principal assistants. They were Batchelor, Kruesi and Upton, in alphabetical or chronological order. Each played his major role as assistant to Edison, and each had the capacity for executing things that the other two were not adapted to undertake. But all worked under the direction of Edison, who was the master mind. What the one or the other of the three did after Menlo Park when the work was finished is a question belonging to another epoch in the history of incandescent lighting. Then, of course, constellation was changed and the practitioners came forward to satisfy the urgent demand of the public to give them the system that had now been worked out theoretically and practically at Menlo Park.

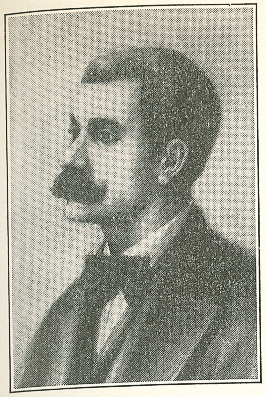
Another work which Edison took up in the midst of the many problems of 1880 was the crystallization of his ideas on the network with feeders to be used in the proposed New York City central station. I remember the many discussions he had with Upton on this subject. They related to the exact places in which to lay the feeders so that a constant potential would be maintained. It would be easy to plan, said Edison to Upton, if he knew how the load would be distributed. He then burst out with, 'I will get an estimate by hiring men to canvass the district we intend to light. I will have printed sheets in which the canvasser will note the street number of the house; lighting, whether by gas or not; the

number of gas jets used and about the time they are in use each day; power employed, its form of production and its purpose,' etc. In that way the best practical insight could be obtained into the whole problem. While talking further with Upton and questioning about this and that, he again said suddenly, 'I've got it! I will have a large board made and on it we will build a miniature model of our proposed station to scale. With the information the canvassers bring, the load can be represented by tiny resistance coils, and then we can plow along and determine the best points at which to connect the feeders. We can also study the bridging effect of the distribution lines at street corners and the whole network. We will use a couple of very large bluestone cells for the central station power, because they are constant and with one or one and a half volts can be so magnified with the Thomson reflecting galvanometer that its beam of light can be adjusted to 110 or more divisions on the scale. Working relatively in that way we can obtain some nice figures and data for central station network. I am going to get a man who will devote his whole time to this matter and I want you (Upton) to break him in. In fact, I received a letter the other day from a foreigner who says he was formerly an officer with the Austrian Telegraph Corps.'

'As an officer in the Telegraph Corps he must have had an academic education and no doubt will be a good man for this work,' replied Upton.

Not long after this conversation Edison had a squad of men canvassing the district in the lower part of New York City which he intended to light. The canvass sheets presented very interesting information and many of the citizens pledged themselves to use his light and power as soon as his proposed central station was in operation. Many who were using kerosene lamps wrote that they were impatiently waiting for his light, and so did some who were using animal power (horse or mule) for operating freight elevators in some of those old-fashioned three-storied brick buildings that in the very old days had been inhabited by the better class of householders. Perhaps some of the old-timers in New York will remember some of those little warehouses in the streets east and west of Broadway, downtown, where a horse was used in the cellar to operate a crude sort of freight elevator.

I think it was in August, 1880, that Dr. Herman Claudius came to us; he was the foreigner whom Edison had men-



DR. HERMAN CLAUDIUS

tioned to Upton as the one to do the preliminary soundings on a miniature central station network. He spoke but little English and Upton was often forced to use the German he had learned while studying under Helmholtz in Berlin. We soon found that Claudius was an educated man of the old school and that he was extremely accurate in all his calculations, going over them twice or oftener in order to check first results. Like Upton he slung his logarithms about with a facility that commanded respect. Upton explained Edison's ideas on the matter and Claudius grasped them immediately, for he was not only drilled as a theorist, but had had plenty of practice as an engineer. As the whole telegraphic system in Austria as well as in other European countries is a State concern, Claudius had served in a civil as well as in a military capacity.

A large solid board was now made having a length of about 15 feet and a width of about 12 feet, and on this board the district that Edison intended lighting up in New York City was accurately drawn to scale. Distribution mains bearing a fixed ratio to the ones intended for use were carefully placed in the streets indicated on this wooden map. These mains were interlocked at corners and the greatest care was taken in every way to insure that the whole was really an exact miniature. The sides and blocks of each street were dotted with tiny resistance coils representing the expected load the central station would have, these loads being calculated from the canvass sheets. All the work was done by Claudius himself, except that of winding the coils. He gauged and measured everything; the job called for patience indeed.

Often Edison (and sometimes Upton too) would sit on a high stool and discuss the situation with Claudius, pointing out this or that on the large board map. The main work at first was to get the distribution mains with their load, and an extra percentage added for growth in the years to follow. When Claudius had that task finished the most interesting

part came. This was a fine model of a central station's distribution network on a small scale though one large enough to enable seeking the facts and determinations.

With meticulous fidelity and mathematical precision Claudius put the network into tangible form, all proportioned, even to the length of the streets. Edison was pleased and asked Upton how successful such a work would be if attempted on paper with pencil and logarithms. Upton admitted that it might perhaps be done but that it would be a head breaker and, no doubt, subject to many errors. Edison with pride pointed out the advantage of an exact model which permits eye and brain to work quickly and harmoniously without fatigue.

'I think it's a great way to get results, and,' he continued, 'you must not forget it's an entirely new problem that we are up to and it seems this is the way to solve it. Later on, when experience has been gained, other stations that will be erected will, no doubt do their work without need of models. However, I want to keep on in this way even for some of the other stations. Your dry scientists can in the meanwhile evolve other methods, or no doubt the practical boys that follow will find the way from existing circumstances until it becomes a rule of the thumb.'

Upton then asked, 'Where are you going to place the central station?'

Edison smiled knowingly, which made Upton smile, too, and said, 'I don't know yet. I shall divide the whole district into imaginary sectors. Then Claudius can begin putting in feeders with the station tentatively located in this and that sector. We shall then have an approximate picture of the cost of feeders as well as find the point where they ought to be connected with the distribution mains to serve best. Of course, I can't tell now where the station will be, for that depends on circumstances, and at present we are ahead of the times. Who knows where I can get the property to build a central station for our first district? It must be somewhere between Wall Street and Spruce Street from Nassau toward the East River, you know. That's the reason I gave Claudius the job of getting the data for a central at various points. Then when I know where it is to be, I shall need only to choose this or that plan, as they do in the war offices of nations, and go ahead.'

Thus it was that Edison's resourcefulness visioned a

method of solving a new problem that was enough to give anyone else the nightmare. It was a great pioneer stroke and engineers of today can surely view it with respect, and wonder at how definitely he knew his business. Edison's brain was a compendium of solid facts based on common sense, and his energy supplied the static and dynamic power that kept all of us at the laboratory a-going. Characteristic of his strategy was the fact that he knew how to segregate his picked men for special purposes and then get them into action without unnecessary detail. The results were what he wanted, results clear and plain, results that would appeal to common sense and make the whole situation easy to comprehend. Claudius and Upton, his tutor, had accomplished all this with their combined abilities. Edison now had a workable map on a fractional scale with which network and feeder problems could be worked out in simple and lucid manner.

The world in general knows little of the important role filled by Upton, for he was modest and reticent. Perhaps an idea of his qualities can be obtained best from Edison's own words when he heard of Upton's passing on March 10, 1921. He said:

'Mr. Upton was one of my old pioneers. He was a loyal worker and as a mathematician assisted me in working out the complicated problems of economy and the adaptability of the devices necessary to make a complete system of electric light by incandescence. He was a very fine man.'

To professionals and those who can imagine what obstacles Edison had to overcome before achieving his successful lamp, dynamo, and practical distribution network with feeders I am sure his terse eulogy of Upton will convey a profound impression of his status as an assistant in the salient problems that once confronted him.

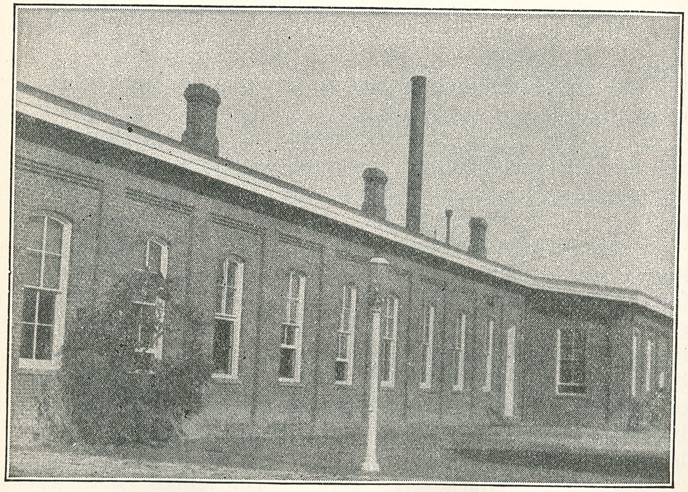
Upton in an autobiography once wrote, 'Now as a gray-haired man, with my active life behind me, I am thankful for much. I had a clean and godly ancestry. I had the joy of study with pleasant mates and the thrill of many warm friendships. I have sat at Edison's feet and he has called me his friend. To my beloved country I owe the opportunity of making good by work after misfortune. My family life has brought me to old age with a deep gratitude for mutual love and affection.'

These lines characterize Upton, gentleman, scholar and real Edison pioneer.

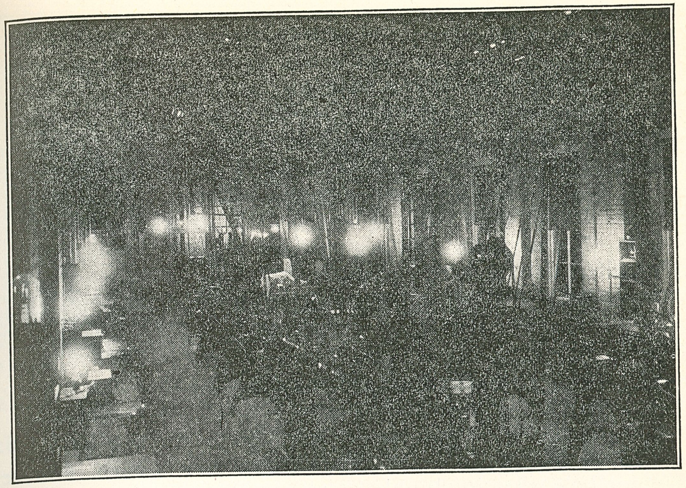
As to the work again that Edison originated and had Claudius put into shape, it was easy to obtain from it all the network data necessary in a short time after the site of a station had been determined. And so it happened that when Edison bought the property at 255 and 257 Pearl Street, New York City, as the site for the world's first central station it was soon clear what copper investments he had to make for distribution and feeder mains.

Edison often talked with Upton on the amount of current the lamps consumed and said he was certain that in the near future the lamps would be improved so that less current would be necessary.

Edison patented his feeder system for electric networks. He signed the specification on August 4, 1880, and the patent was granted on September 19, 1882, under No. 264,642. This master stroke of engineering saved enormous quantities of copper as against what would be necessary if only a straight multiple arc system or one designated as the 'tree system' were employed. Calculations were later made showing the respective merits of the 'tree system,' which is a simple multiple arc system, and one in which feeders were employed, the lamp load and positions being the same in both cases.



Brick machine shop at restored Menlo Park.



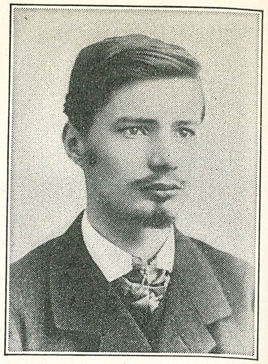
Interior of restored brick machine shop illuminated at night.

The results were surprising. The 'tree system' required six times more copper than the feeder system to maintain equal uniform pressure.

Edison in his patent says, 'This invention relates to a method of equalizing the tension or "pressure" of the current through an entire system of electric lighting or other translation of electric force, preventing what is ordinarily known as a "drop" in those portions of the system the more remote from the central station, and also to other features in systems for the utilization of electricity.'

Lord Kelvin (formerly Sir William Thomson), one of England's great scientists, was once asked why someone else had not invented the simple feeder system, and he replied, 'The only answer I can think of is that no one else was Edison.'

When Claudius was later engaged in making other miniature station networks, Edison gave him an assistant by the name of Hermann Lemp, who came to Menlo Park in December, 1881. Lemp had seen the Edison exhibit at the great French Exposition in Paris in 1881 and was so impressed that he resolved to go to America and work for Edison. At the Edison headquarters at 65 Fifth Avenue, New York City, he was hired by Charles L. Clarke who sent him down to Kruesi, then in charge of the Edison Electric Tube Works at



HERMANN LEMP, assistant to Claudius.

65 Washington Street. While there he assisted in testing the tubes and in a short time was sent to Menlo Park to assist Claudius in making the small resistance coils that represented the lamps in the district to be lighted up.

In a reminiscent letter written to me Lemp says among other things: 'We arranged to have units of resistance like the units of money, 1, 2, 5, 10, 25, 50, 100, and each denomination had a different-colored glass bead by which it was known. The coils themselves were made up from double cotton-insulated German silver wire, and were wound on the spools in the same manner as the coils in a resistance box, that is, double. The spools were about 3 inches long by 1 inch in diameter, and the ends were brought out at the top and dipped into melted paraffin. They were then adjusted exactly by means of a Wheatstone bridge and Thomson reflecting galvanometer. When this was finished they were provided with copper terminals for connection. When thus far completed they were covered with hot asphalt and held on the board of the miniature station at their proper place by a nail driven through the spool.'

Lemp said that Claudius was so exact that he insisted upon washing the board down every morning to free it from dust. I myself remember when he was working on the Pearl Street central station task he had the board well polished and shellacked, and covered with a cloth every night.

Lemp also relates an interesting personal observation of those days of 1882. 'What shall I call it—intuition or insight? One morning Edison came into the laboratory and took a place by the miniature station board where Claudius was locating feeder positions. He sat down on a chair and after studying the situation said to Claudius, "I think I should place a feeder here and one there," in each case pointing to a particular location on the network. Claudius very politely listened to what Edison had to say, but to tell the truth, paid not the slightest attention to it. Claudius was an Austrian army officer of very set habits—everything had to

be done just so, and he always used seven place logarithms when a computation in the head would have been just as good. He was thorough and painstaking, but slow—terribly slow. Well, unbeknown to Edison and Claudius, I made a mental note of where Edison pointed and afterwards marked the places in a peculiar way.

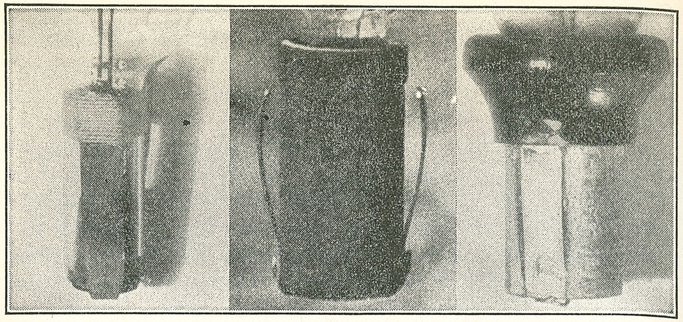
'As I have stated before, it took us a long time to complete the job, and times and times I steered Mr. Claudius in the direction of the points indicated by Mr. Edison for the location feeders, which was always grumblingly acknowledged.

'The fact of the matter is, that if we had taken Mr. Edison's guess of that morning and located the feeders where they were finally located, we should have been near enough for all practical purposes, inasmuch as many changes had to take place afterwards in the number of lights actually installed.'

Among other station networks that were determined in this way was that of the city of Milan in Italy.

The Milan Edison central station was the first erected in Europe and the second of the real commercial stations in the world. It was not an exhibition or small shack station hurriedly thrown up like a circus tent, but like the Pearl Street station, was built on the engineering plan by engineers, and was erected to stay. In a short time it out-rivaled the old original station in Pearl Street, New York City, for it had ten Edison steam dynamos, known as jumbos; and when Deri, Zipernowsky and Blathy solved the transformer problem with alternating current in 1885, they were among the first to use the method for distant consumers. They also used the Thomson-Houston arc light system and worked electric tram-cars. In fact, the Milan Edison central station was for a long time the best-managed central station in Europe. It was also the first Edison station to take such strides in progress as to use direct current and alternating current. I hope later to describe this station. The men whose energy and initiative built and fostered that station were Professor Guiseppe Colombo and Dr. John W. Lieb—two great Edison pioneers.

The solving of the network problem for central stations in those early pioneer days received favorable comment from many scientists and others, and even as late as 1906, Professor Francis B. Crocker, of Columbia University, New York, said, 'This plan can be followed in any case, but would ordinarily be considered too much trouble, although it might often effect a considerable saving in, or better arrangement of, the copper.'



Different lamp bases for the carbonized paper horseshoe lamp. In restored Menlo Park laboratory, Dearborn.

LXXVII. Bergmann & Co.

(PART ONE)

IN PREPARING for his second and final demonstration of the lamp in 1880, Edison improved the socket and the lamp base. As I have already shown, the experimental socket of 1879 was based upon the principle of the telegraph jack switch. This consisted of a wooden receptacle in whose hollow two vertical brass or German-silver strips were placed.

The lamp base consisted also of two strips, which when slid into the socket completed the connection. It was improved soon by attaching the metal strips to wood instead of tying them, as in the first lamp bases, with thread.

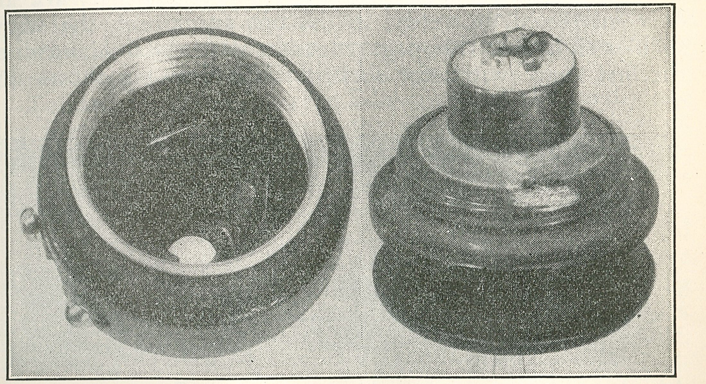
In the first sockets, a simple thumbscrew was turned to make or break the current; this also served to hold the lamp a little more securely when the current was on. The whole affair, however, was so unstable that a lamp could not successfully hang downward, because it would soon fall out of the socket. It always had to be upright, and was shown in that position during the first exhibition of 1879-80. These and other accessories were all made in a great hurry because the New York *Herald* article of December 21, 1879, had appeared before Edison was ready. He wanted to put some extra touches on the exhibition, which to finish would have required a few weeks more.

When preparations for the second exhibition got under way, Edison took up the subject of socket and lamp base

again. He knew these must be constructed so that a lamp could be held securely in any position, and at the same time furnish a good electrical connection. He recognized that the jack switch, like the thumbscrew that served as a key, would not fill the bill.

One night in the early part of 1880, while the master was talking on this subject to some of his assistants, he noticed a kerosene oilcan standing near. Taking it up and unscrewing its cover, he studied the combination for awhile and then exclaimed, 'This most certainly can make a bang-up socket for the lamp, as well as a base!' Thus the Edison screw socket and lamp base of 1880 were born. The bases of both were of wood, and in the socket the female screw was placed at the upper end; below the screw were three inverted U metal springs at equal distances one from another. The lamp base had a male screw and cylindrical ring. When the latter was screwed into the socket, it was forced between the U springs and made a good contact. In some of these sockets Edison inserted a snap-key switch which like the screw shell was the first to be used in incandescent lighting.

It is of historical interest that Edison was the first to employ the screw shell form of socket for holding the lamp and forming a part of the electrical circuit. An English writer in the London *Electrician* once gave this indirect eulogy of Edison:



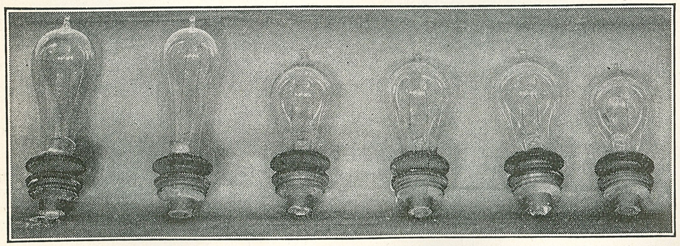
Edison lamp base and socket with screw, 1880. Originals in restored laboratory at Dearborn.

'The carbon glow lamp had not been invented many months before a holder was found to be necessary. It is natural that Edison should have been the first to design and patent such an arrangement; for from the beginning, long before a practical lamp had been discovered, he was arranging for mains, meter, switches and a score of details by which electric light might be introduced into daily life.'

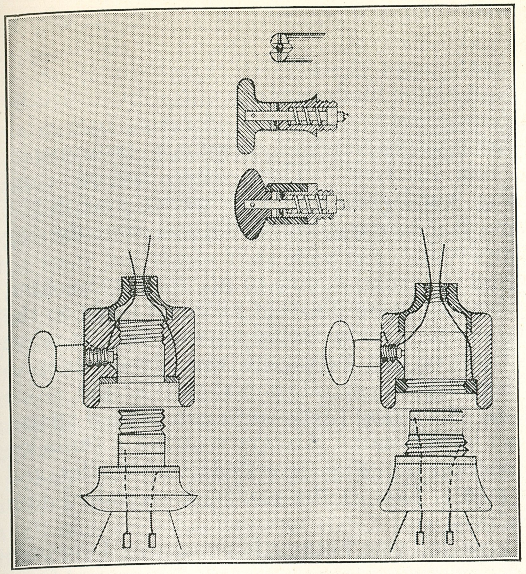
The chandelier that Upton had in his private residence near the railway station at Menlo Park was fitted with these new type sockets having snap keys. Often the distinguished visitors who came to the laboratory inspected the lights and sockets at Upton's house. The lamps in the Upton chandelier were all placed in an inverted position in contrast with those used in the first sockets.

The importance of the screw part of a socket and lamp base as well as the snap switch is recognized when one considers that millions are used in almost every country on the globe. The idea of using the screw shell solved the problem in a simple and perfect manner. One wonders why it was not conceived at the start. Edison's genius also saw that a new kind of switch had to be made for his system which should be able to make and break current instantaneously, with a key that could be turned right or left as was desired.

Edison applied for a patent on the screw shell and snap switch on March 7, 1881. It was granted on December 27, 1881, being No. 251,554. In the patent drawings Edison showed several sockets based upon different lines. We are only interested, however, in the one containing the screw shell as shown on this page, together with the mechanism of the first snap switch for sockets. The drawing shows one



Row of bamboo lamps with Edison screw shell lamp base, 1880. (Now in restored Menlo Park laboratory.)



Drawing from Edison screw shell patent for lamp sockets and base. Note simple, effective drawing of first snap switch principle in electric incandescent lighting.

screw shell at the top and the other at the bottom of the socket, or lamp base.

The second terminal in the socket, or lamp base, shown in the drawing, consisted simply of a metal ring. On a previous page is a photograph of the first Edison screw shell keyless socket and lamp base taken from the originals now in the Edison laboratory in Greenfield Village.

Toward December of 1880 Edison remarked casually one day that it would be better if the metal ring at the bottom of the lamp base were given the form of a cap. The change in the form of the socket and lamp base came about in this manner:

At the onset the sockets and other parts were manufactured by Bergmann & Co., of which the three partners were Bergmann, Edison and Johnson. Bergmann, after leaving the employ of Edison's Newark shop, settled in New York City about the same time that Edison moved to Menlo Park. Edison had a high esteem for Bergmann not only as an excellent mechanic and instrument maker, but as one blessed with enviable traits that later developed into remarkable executive

and business abilities that made him the founder of the electrical accessories industry.

Bergmann's efforts were the first in that industry. His energy, integrity and vision made him one of the most successful and active Edison pioneers. Edison intrusted him with manufacturing phonographs, carbon telephone transmitters and chalk telephone receivers. Then when Edison commenced introducing his light, heat and power system the firm of Bergmann & Co. was formed, Edison contributing ideas, help and goodwill.

Bergmann was a congenial friend to all who knew him, and I well remember the many pleasant visits he made to the Menlo Park laboratory. Edison would explain to him what he wanted manufactured and Bergmann was always sure to carry out the instructions to Edison's satisfaction. He possessed the knack of putting things into commercial shape, an ability of great importance. Always wearing a smile on his jovial countenance, he was nevertheless a hustler and shrewd business man. That is the reason some called him 'sharper than Shylock.'

I don't recall how Johnson became his partner; I suppose that under the circumstances it was a case of *force major*. Concerning Edison's partnership in the concern let me relate in the words of Charles L. Clarke, veteran pioneer:

'How Edison became a partner in Bergmann & Co. has an amusing side, told me by Bergmann with some feeling of disappointment and chagrin, for he strongly had the dollar-in-pocket instinct. One day, after Bergmann & Co. (Bergmann and E. H. Johnson, partners) were making the Edison light fixtures, sockets, switches, etc., Johnson, with his bold promoter assurance (Bergmann was there), asked Edison how he would like to become a third equal partner with them. Of course, Edison jumped at the chance and inquired: "For how much?" At which Johnson (wise man) said: "For nothing but goodwill." There was a warm handshake to close the bargain, although it must have given Bergmann chills, for as he said to me in telling the story, "Edison would have been glad to pay us fifty thousand dollars!" As the future showed, it was really a good bargain for Bergmann, for Edison contributed much of his ingenuity to the concern. This happened in the early part of 1881. As among those three partners, the details of their many experiences have mostly passed away with them. Edison once said laughingly: "I got all the glory, and Bergmann all the money." Years later, when Bergmann, the millionaire, left America, Edison wrote him a nice letter which contained the following, "You have nothing to thank me for, as hundreds of others of my companions and employees have had the same chance. Your commercial success was your own doing and I only gave you the opportunity." '

Edison gave all his men opportunity; when they did not take advantage of it but ran along with the crowd, it was not his fault but theirs that they remained behind.

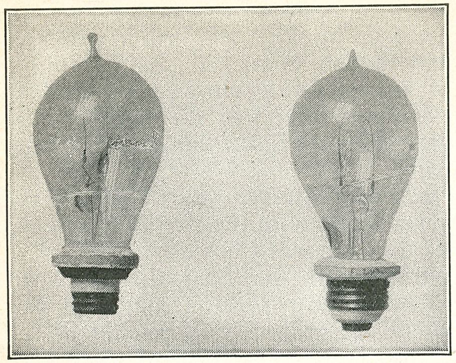
Coming back to our subject, the Edison screw shell for sockets, lamp bases, and other parts, I may say that Johnson took out a patent for a bevel ring instead of the straight one shown in Edison's patent and illustrations. Of course, he included in his patent drawing the main thing, that is, the Edison screw shell, which, however, he could not claim.(1)

Some of the lamps and sockets that were sold in 1881, in fact the first ones, were fitted out with the Edison screw shell and the Johnson bevel ring. It was soon found that the bevel ring was not practicable for lamp bases, and complaints poured in. Both the screw shell and the bevel ring were held in position by plaster of Paris. Plaster of Paris mixed with gum tragacanth was employed for many years in fitting out the lamp base, and in 1900 porcelain was first substituted by the General Electric Company (which in 1892 had consolidated the Edison, Thomson-Houston and Brush interests into one company).

Use of the first bevel ring lamp base soon disclosed that screwing the base into the socket put a tensile strain on the plaster of Paris base and broke it. Thus ended the usefulness of the bevel ring patent.

Recognition of these facts caused a commotion at the shop of Bergmann & Co. Edison and Bergmann put their heads together, and no doubt Edison confided that he once had thought of making the straight ring into a cup to fit the lower part of the lamp base. It seems that Bergmann then got the idea of making a small cap instead of a large one, as Edison had thought to do, and of placing this on the bottom tip of the base.

(1) His patent application was filed on May 27, 1881, and his bevel ring patent was granted on December 27, 1881, under No. 251,596.



Extreme left—Edison screw shell with Johnson's bevel ring. Right—Edison screw shell with the Bergmann cap tip. (Now in restored Menlo Park laboratory.)

Edison thought the idea was good and told Bergmann to get it patented in conjunction with his screw shell. The Bergmann patent application was filed on February 25, 1882, and granted on May 2, 1882, under No. 257,277. This combination was the genesis of the universal lamp base and socket used everywhere.

I wrote once to Clarke on the matter, and he said, 'Your statement and sketches about invention of the lamp screw base and co-operating socket agree with my views on the matter. Edison was the first to invent the screw principle . . .

'It must be kept in mind that Edison did the fundamental inventing of the screw base and socket, and that his commercial form was mighty good, although that does not mean improvements were impossible . . . But the underlying credit is Edison's. *Facile est inventis addere*, some one once said —meaning "It is easy to add to things invented"—or to improve an invention. So, that's that. We won't allow anyone to undermine Edison's reputation for gigantic inventive ability—the greatest ever.'

This has always been my contention, too; for the screw shell that Edison patented was the basic step in making the lamp base and socket a universal and standard article.

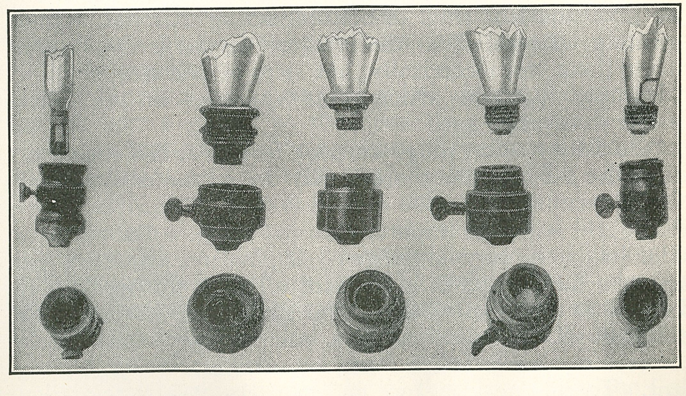
Bergmann once wrote me:

'In writing Mr. Edison's history you must be careful to state that he has been the prime inventor and is entitled to all the glory belonging to him, and that we others only have been his staff and help in carrying out his inventions. It has been due to my lucky star that I was associated with Edison in those early days.'

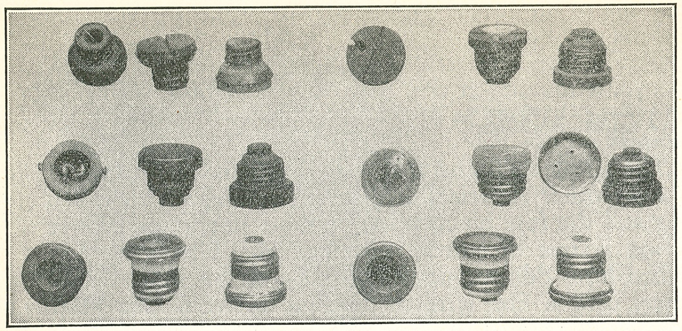
I and others can attest that Bergmann never appropriated any credit to himself and that he was always a loyal friend and partner as long as he was in any way linked with Edison interests.

The screw shell and the little cap found their application in many other electrical accessories, among which the safety plug and the fuse block played a most important part in the Edison system of current distribution. I have already described how Edison, while working on his first electrolytic meter, used a fine wire as a shunt between two platinum points. He wanted to preserve these contact points from the destructive effect of arcing and found when an intentional short ciruit was made, the wire was fused and the contact points were relieved from the greater effect of arcing. In the first experiments we used copper, then lead, and afterward an alloy. March 10, 1880, Edison made a patent application for a 'Safety Conductor for Electric Lights.' The patent was granted in May, 1880, as No. 227,226. In it he said:

'This safety device consists of a piece of very small conductor interposed in the main conductors of a house or in the derived circuit of a lamp. Preferably, one is interposed in the circuit of each lamp or other translating device. This small conductor has such a degree of conductivity as to allow readily the passage of the amount of current designed for its particular



Stages in development of Edison lamp base and socket from 1879 to 1883-84. (Now in the Edison historical collection at Dearborn.)



Development of Edison screw shell fuse plug. Top row—Pioneer Edison fuse plugs of wood, 1881-82. Middle row—Fuse plugs, 1882; glass plugs, 1885. Bottom row—Modern standard fuse plugs. (Pioneer plugs now in the Edison historical collection at Dearborn.)

branch, but no more. If, from any cause whatever, an abnormal amount of current large enough to injure the translation devices or to cause a waste of energy is diverted through a branch, the small safety wire becomes heated and melts away, breaking the overloaded branch circuit. It is desirable, however, that the few drops of hot molten metal resulting therefrom should not be allowed to fall upon carpets or furniture and also that the small safety conductor should be relieved from all tensile strain; hence I inclose the safety wire in a jacket or shell of nonconducting material, which, preferably, is secured to the ends of the large conductors, uniting them, not electrically, but as to tensile strain.'

I quote from an article that appeared in the *Edison Monthly* some years ago:

'The Edison safety plug—cut-out, fuse, or as it is commonly called, the "Edison Plug"—is today one of the most remarkable links contained in the general system of electrical distribution, and is just as important as any of the other adjuncts, while its elementary simplicity, originality, efficiency and cheapness have made it a standard all over the world. Its efficiency as a protective device has enrolled it in the statute books of all communities as a compulsory article of use wherever current is taken from a central station or isolated plant. To the fire insurance underwriters, it acts as a silent guard at every point where it is stationed, and no policy

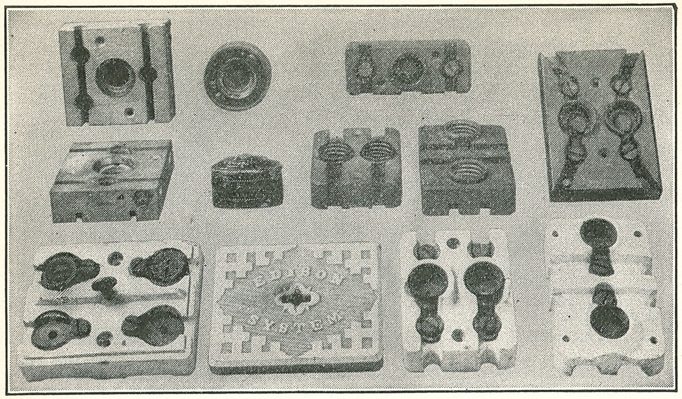
can be issued for any building where current is employed that is not policed by the Edison plug.'

The fuse is an ever alert watchman whose sole mission is to keep too much current from flowing into a given circuit. At any attempt to impose upon it, it melts and quits work, and the lights, motors and other machinery cease working. Thus its warning is always effective and is always heeded. Without the fuse the same effect would have been evident somewhere else in the line, probably in the walls or in some less accessible place, and the results would have been disastrous. Originally it was sold at thirty-two cents, and was only procurable at electrical shops. Today you can buy it for a nickel in almost any kind of store. Despite its cheapness, there is still an occasional thrifty soul who replaces a burned-out fuse with a copper slug or some other makeshift arrangement, thus removing from the circuit the very essential weak point which should be there for his own protection. In the United States we call it the Edison fuse plug; in France *bouchon d'Edison;* in Germany Edison *stopsel;* in Italy *turacciolo* Edison; in Spain *tapon* Edison; in Hungary Edison *dugasz.* In other countries the name Edison is incorporated with it.

We made them first with plaster of Paris, and then with wood, glass and, finally, porcelain. The fuse plug, I may say, stood in the same relation as the lamp base to the socket. The fuse plug receptacle was a fuse block placed at accessible points so that the plug could be removed or replaced when necessary. It, like the rest, went through periods of development from wood to porcelain; yet like the lamp base, sockets and plugs, its appearance has changed but little since the beginning.

The simple Edison fuse plug is not alone to be considered. Let us take a glance at the fuses that Edison's marvelous ingenuity brought into being when they are required beyond the range of a plug. I refer to those heavy fuses on switchboards that protect main lines; they in themselves created a side branch or industry known as switchboard engineering. When we talk of Edison's inventions in electric lighting and power transmission we are likely to consider only the lamp and the commercially efficient dynamo. These were only a part of the system. What Edison created was *a complete new system of electric lighting and power distribution.*

Emil Rathenau, the founder of the German Edison Company, which later changed its name to the *Allegemeine*



Development of Edison fuse block by Bergmann & Co. Top and middle row—Edison fuse blocks of 1881-82. Bottom row—Porcelain fuse blocks of 1885-86. (Now in the Edison historical collection at Dearborn.)

Elektricitaets Gesellschaft, said when he saw the Edison system at the great French Exposition of 1881:

'The Edison system of lighting was as beautifully conceived down to the very details, and as thoroughly worked out as if if it had been tested for decades in various towns. Neither sockets, switches, fuses, lamp-holders, or any of the other accessories necessary to complete the installation were wanting, and the generating of the current, the regulation, the wiring with distributing boxes, house connections, meters, etc., all showed signs of astonishing skill and incomparable genius.'

On another occasion Rathenau said, 'The year 1881 was a milestone in the history of the *Allegemeine Elektricitaets Gesellschaft*. The International Electrical Exposition at Paris was intended to place before the eyes of the civilized world the achievements of the century. Among the exhibits of the exhibition was the Edison system of incandescent lighting. *It became the basis of modern heavy current technics.*'

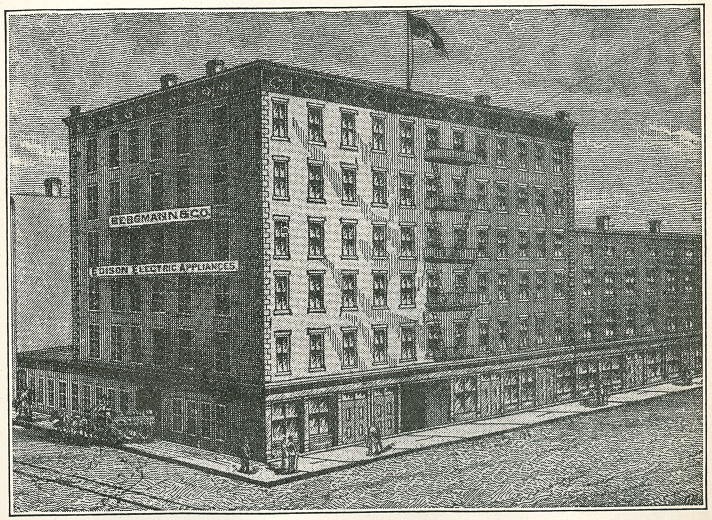
Edison had many irons in the fire and each he forged out with admirable skill and vision, and when they were finished and a complete system of lighting was born, it was a stupendous feat. A new world came into being and antiquated methods in the arts were gradually remodeled, creating new

industries possible only through the labors of that great man who worked at the magical Menlo Park laboratory.

Coming back to the Edison screw shell, I may mention that it is not only used for sockets, lamp bases, fuse plugs and blocks, but also in many other ways in the art as a connector. We must never forget when mentioning the firm of Bergmann & Co. that it was conducted by two resolute men, Edison and Bergmann. The first gave his time in furnishing the second with ideas to be worked out in a practical and commercial way. What the first understood in creating, the second understood in materializing. There always existed perfect harmony between the two; theirs was a warm and congenial friendship. One helped the other in launching a great cause, in which it represented an important division of the whole.

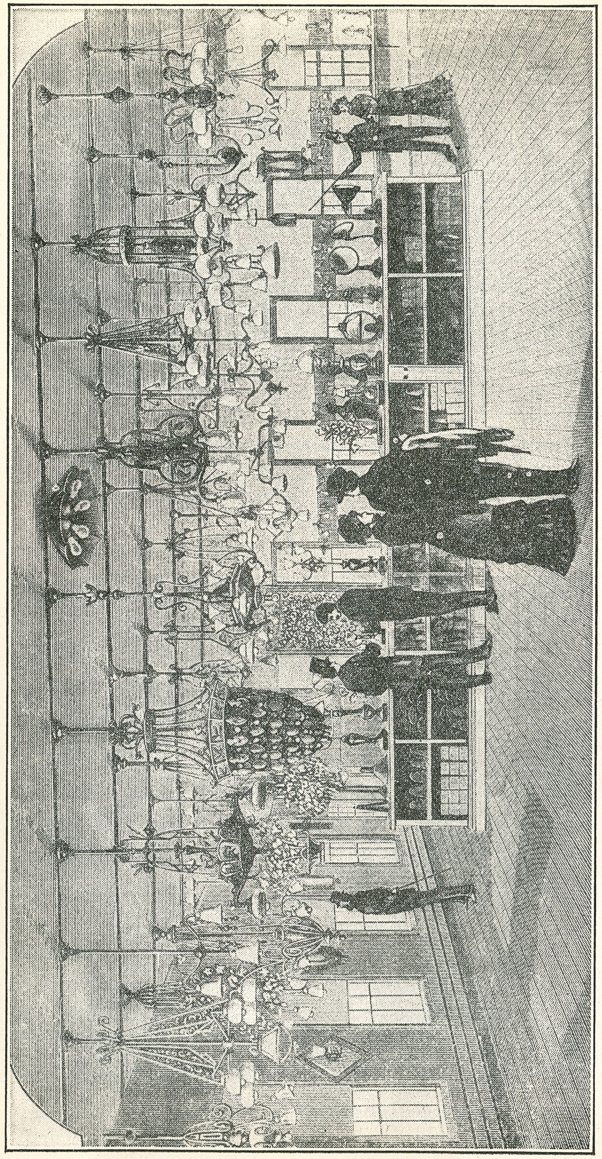
Edison said:(2)

'Bergmann was a man of great executive ability and carried economy of manufacture to the limit. Among all the men I have had associated with me, he had the commercial instinct most highly developed.'

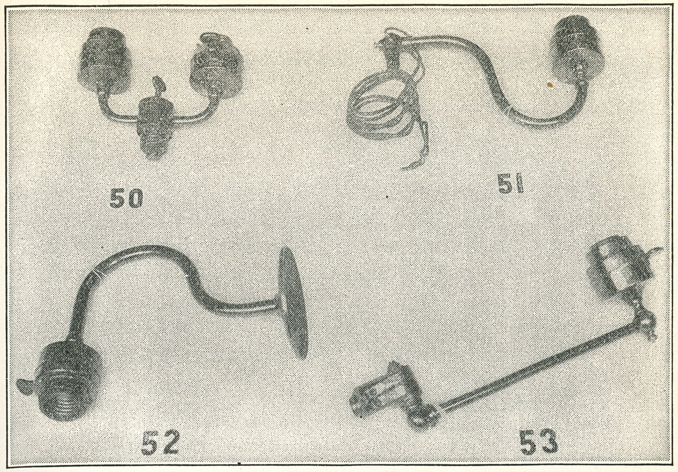


Bergmann's factory, New York City.

(2) Dyer & Martin, page 757.



Showroom of Bergmann & Co., at Seventeenth Street and Avenue B, New York City, 1883, first of the kind in electrical history.

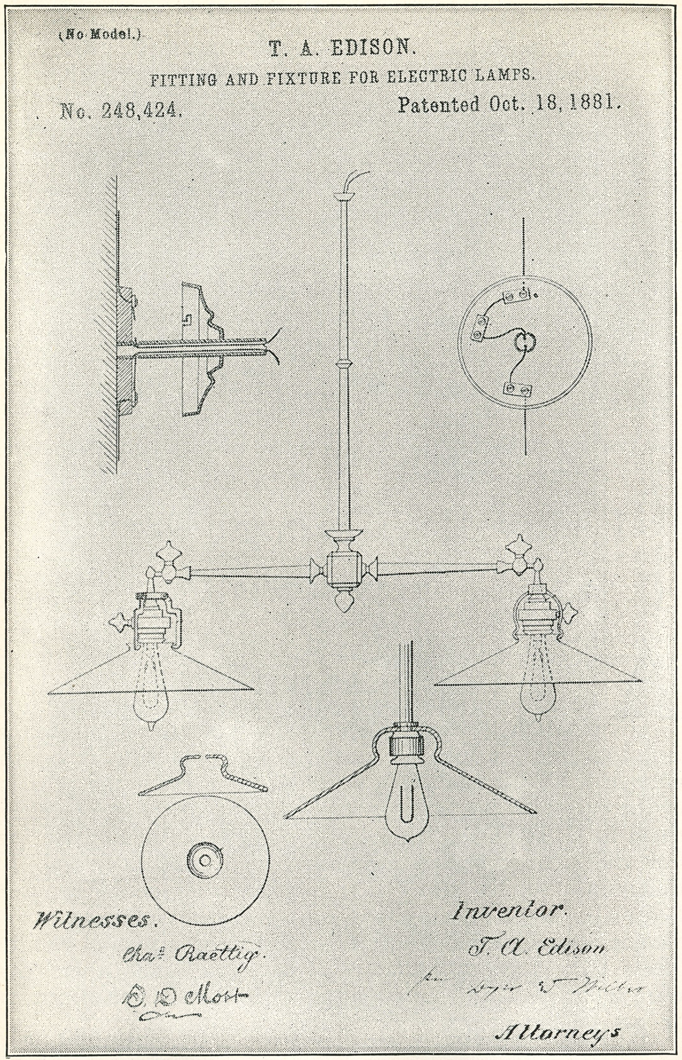


Early bracket fixture made by Bergmann & Co. for the Paris Exposition of 1881.

LXXVIII. Bergmann & Co.
(PART TWO)

ANOTHER branch of accessories that Bergmann & Co. started was the electric light fixture industry. The first fixture was made at Menlo Park, where we took a Michell Vance Company's four-armed gas fixture and converted it into an electric one by wiring it on the outside with red and green wires to distinguish the polarity of the current. We wired two such gas fixtures and installed them in Edison's residence for the 1879-1880 demonstration. For the same occasion Bergmann made one of wood, for Edison wanted to show that any material could be used. Bergmann & Co. made many different kinds of fixtures and chandeliers, some of them showpieces for size and beauty. There were fixtures exclusively electrical, and others that were what we used to call 'combination ones,' for electricity or gas. Chandeliers were called 'electroliers.'

It is a curious fact that some of the minor parts employed in the Edison system took longer to develop than the ones upon which the system is based. The droplight, or pendant,



Patent drawing of the first ceiling block by Edison.

was one, the ceiling block was another. We at Menlo Park simply took two wires and twisted them together. They were unsightly, because the stiff wires dangled in every shape and form. Flexible cord for electric light use did not as yet exist; the only kind known was used in telegraph or telephone work. This cord was in no way suitable for electric lighting; it had neither the capacity nor the insulation to carry the current required. Edison soon recognized that flexible conductors or cord would be a most welcome innovation, and he prevailed upon wire manufacturers to get up something in the way of a flexible stranded cord, single and double, and well insulated. Of course, to turn out such a cord required first the designing of special apparatus and then the making of it and other equipment, all of which required time and practice. It was only toward the end of 1883 that an inferior double cord appeared on the market selling at about 10 cents a foot.

The droplight came first. A method of suspending it from the ceiling next engaged the attention of Edison, with the ceiling block as a result.

In a patent application dated March 8, 1881 (which was granted on October 18, 1881, under patent No. 248,424), Edison describes his arrangement of a ceiling block as follows: Upon the ceiling or other support is fixed a base piece arranged to receive and support the stem of the chandelier. To this are fastened the line conductors, in one of which is inserted a small piece of lead fuse wire. From the base the conductors pass to the interior of the chandelier. Means for covering and protecting the exposed contact pieces of the ceiling block are provided in a metal canopy made to fit over the base plate and held there by a bayonet lock. An aperture in the center of this cap was of sufficient size to permit its being slid up and down in case a blown fuse wire had to be replaced. This ceiling block was good not only for chandeliers but for any fixture, including the droplight. I may mention that fuse blocks were also used for suspending droplights when they appeared. Bergmann & Co. made a variety of them.

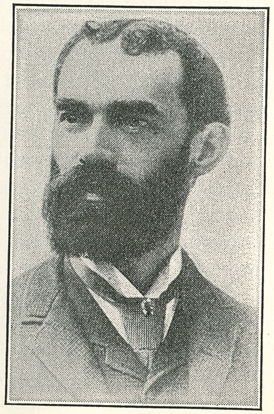
The idea of a flexible pendant was conceived in the fall of 1881, and the first one used was in the home of Edison at Menlo Park. This first pendant consisted of a double piece of webbing tape, with two wires sewed between its sides. It was originated by Luther Stieringer, an expert gas engineer and inventor who entered the Edison service at that time and

Before the flexible electric cord was brought out, this pendant conductor was used. (Now in the Edison historical collection at Dearborn.)

became the first pioneer in display electric lighting with the incandescent lamp. Clarke, the old-timer, declared: 'Luther Stieringer was the *creator of artificial lighting as a fine art.*'

Stieringer began applying his abilities by showing how efficiently and attractively the headquarters of the Edison Electric Light Company on Fifth Avenue in New York could be lighted. He did the work so skillfully that it excelled anything ever done with gas. He became the Edison company's first illuminating engineer —in fact, the first in the world—creating a new art founded on principles that are still followed today in an endless variety of ways.

His first important success came in 1883 when the Edison Electric Light Company intrusted him with the inside illumination of the Louisville Exposition. Here Stieringer had sixteen acres of floor space to light up, and the so-called experts openly proclaimed it could not be done with incandescent lamps. Stieringer with his men completed the work successfully in six weeks, and the Edison company received four medals from the Jury of Awards. The display of lighting and color effects at this exhibition amazed all who saw it, and Stieringer's illuminating tactics were conceded to be a magnificent success.



LUTHER STIERINGER

As illuminating engineer of the

Edison company, he also concentrated his studies on general illumination in permanent localities such as stores, offices and dwellings. He kept on improving his method of electric display lighting as current became cheaper and lamps and accessories for the purpose became more developed. Among his master creations in the art of which he was the originator were the World's Columbian Exhibition in Chicago in 1893, the Pan-American Exposition in Buffalo in 1901 and the Louisiana Purchase Exposition in St. Louis in 1904. Here the outline illumination of the buildings produced a more beautiful effect than the old fireworks display in our public squares sixty years ago. Luther Stieringer was an artist whose imaginative genius produced striking and stupendous effects with incandescent and arc lamps.

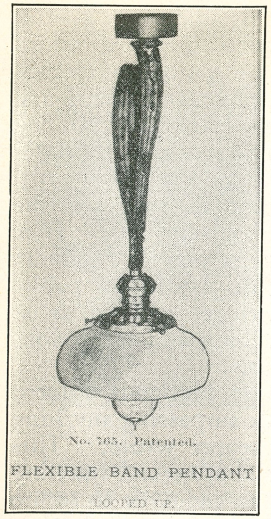
At the Chicago Fair in 1893 his magic, luminous, colored fountain was installed on a gigantic scale surpassing anything of the kind hitherto seen. One newspaper wrote: 'This fountain represents perhaps the most elaborate and startling application of electricity ever made in an endeavor to secure beautiful effects and has been contrived by a man who has won world-wide fame for his success in this line.'

Luther Stieringer as the creator of artificial and flood lighting always produced lavish and unusual effects that thrilled. As master technician in the art he founded, he will always be remembered in electrical history. He died in 1906.

Stieringer began as a pioneer in 1881 and gradually built up the art of artificial electric display. Current became more abundant, lamps improved, wiring facilities and accessories were improved. It was Stieringer who introduced the art of outlining buildings with lamps to produce firework effects. His colored lamps caused the crowds to gape in astonishment. It was Stieringer who made an insulating joint for gas and electric fixtures so that they would not make contact with the ground. Yes, Luther Stieringer was the first expert in the art of fine artificial lighting. He was followed by D'Arcy Ryan, of the General Electric Company, who started in 1903 and built gradually on the foundation laid by Stieringer.

Coming back to the first pendant, I may say that Stieringer improved it. In Bergmann & Co.'s catalogue of 1883 we find the following description:

> 'Flexible Band Pendant—This pendant is admirably suited for mill work and other places where cheapness is desired. The electrical conductors are

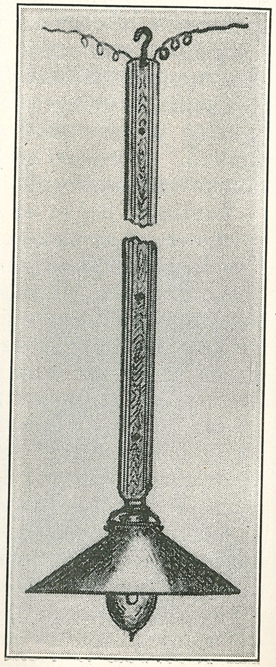


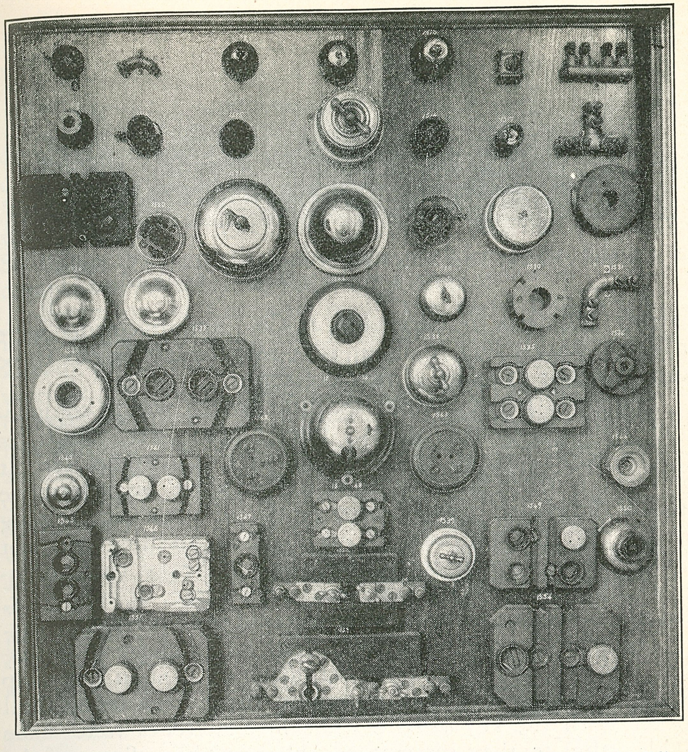
From Bergmann & Co.'s catalogue (1883).

woven into a flexible band which permits raising or lowering the light to any position as shown in cuts. Price plain, 3 feet long including key socket and top plug $2.00 Price per extra lengthening, per foot 12 cents. The plain figure can be ornamented by fringing, embroidering, etc., to suit any taste. It is portable and can be used as a droplight from any electrolier or bracket.'

We perhaps smile when reading the above. We must not forget, however, that it was 'the start,' and that ideas presented themselves like the color designs in a kaleidoscope. When Edison sent me to Europe in February, 1882, I had pendants made of rubber tubing through which the wires passed. Another method which my old friend, Etienne de Fodor, one of the first Edison Pioneers of Europe, originated for the Compagnie Continentale Edison, of Paris, was to screw together two small strips of wooden moulding, with the droplight conductors in their grooves. One end of this double moulding piece was provided with a hook for hanging on the ceiling, and the other end, which was tapered off a little, had the socket affixed.

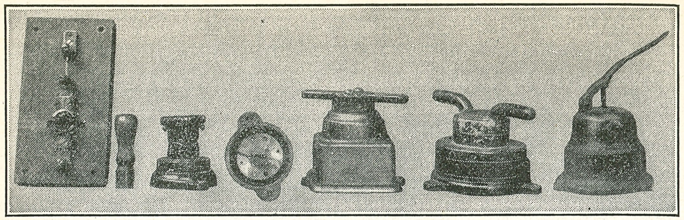
Right — De Fodor's idea of a pendant (1882).





Pioneer accessories made by Bergmann & Co. in early days. (Now in the Edison historical collection at Dearborn.)

One little event of great importance in wiring was that Bergmann & Co. presently came out with ceiling and other blocks in which the line wires could be connected direct without soldering them. Blocks were also made through which branch wires from a main line could be connected without soldering. All these little things which today we pass over without notice when we do wiring work were worked out by Edison and put into practical commercial form by Bergmann. Some of these electrical labor and timesaving devices were patented, for certain reasons, by Bergmann, and others by Johnson, though the original idea always came from Edison. They were partners on equal terms and the

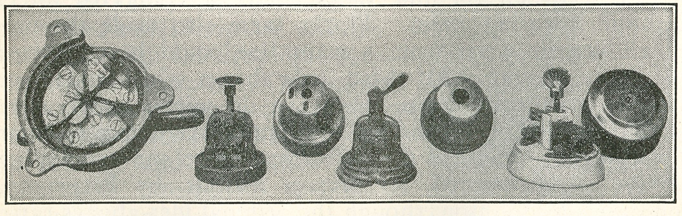


Edison plug and other early types of switches developed by Edison.
(Now in the Edison historical collection at Dearborn.)

patents belonged to Bergmann & Co. Improvements were made constantly and in about 1885-86 porcelain began to be used as a base in many of the accessories.

The evolution of the electric light switch was in conjunction with that of sockets, fuse blocks, etc. Switches existed before Edison; in the old days we called them 'circuit breakers.' When Edison began to introduce his system he studied the switch problem from a different angle, for the plug design that he first used in his dynamo machine was not satisfactory. Edison recognized that in heavy current engineering a switch must have plenty of surface; it must lock, and the break of contact must be so rapid as to prevent arcing.

The first commercial electric light switches for incandescent lighting were made by Bergmann & Co. on the snap action principle, like that shown in the Edison screw-shell socket with the key patent. The first switches were made single; that is, they interrupted only one pole. Some of the early pioneer switches were ironclad and did good service until 1883 when Bergmann & Co. discontinued them. For his generators Edison devised several types provided with a special switch having a wedge grip.



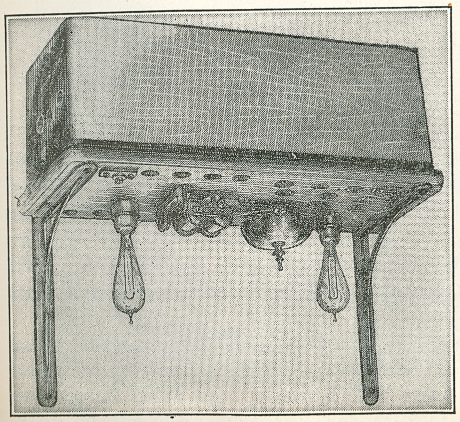
Another group of early switches used by Edison and made by Bergmann & Co.
(Now in the Edison historical collection at Dearborn.)

The bases of all the switches, like those of the sockets, were at first of wood, then of red fiber, and then of various hard compositions and slate; and, finally, of porcelain, in 1885-86.

At the beginning we considered hard, dry wood the best of insulators, and then, as we gained experience under varying conditions we were forced to go over to other materials. Many were the parts, of which the switch was but one, that were required to make the system of distribution perfect. So numerous were they that one wonders how Edison accomplished so much in so short a time.

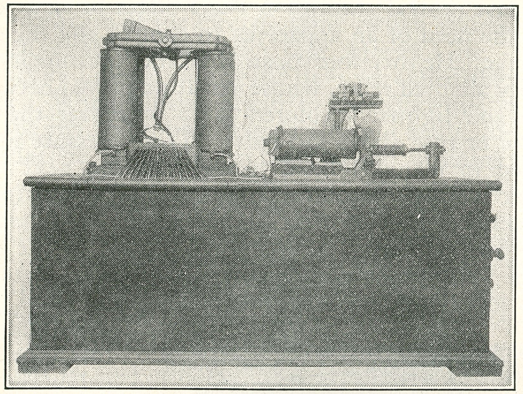
Bergmann & Co. also made the early Edison station instruments, including the Edison electrolytic meters (as I already have said). When Edison began the erection of the world's first central station on Pearl Street in New York, he foresaw the need of an apparatus to control and regulate the line voltage. He therefore constructed the 'pressure indicator,' a specially adapted relay, whose armature played between two contacts and lighted a colored lamp whenever the voltage fell below or rose above 110 volts. These pressure indicators were used in many isolated plants. Edison next made an automatic voltage regulator consisting of a resistance box with a crank turned by two ratchet wheels, one moved by a pawl in one direction, the other by a pawl in the opposite direction. The pawls were each actuated by separate electromagnets so adjusted as to set one or the other pawl in action when the voltage rose above or went below the 110-volt standard. I used these voltage regulators in some of the plants I erected in Europe.

This model was soon superseded by one called the walking beam



Edison's pressure indicator made by Bergmann & Co. in 1882-83. (Note signal bell.)

automatic voltage regulator. In this second type Edison retained the relay voltage indicator and signal lamps and mounted them, together with the regulating apparatus, on one base. The regulating part consisted of two upright bipolar electromagnets. Between the poles of these played a centrally pivoted beam having at each end an armature that was attracted by one of the pair of operating electromagnets at a time. Instead of throwing resistance in or out by means of a crank, Edison constructed a slightly curved commutator having many segments, each of which was connected with a part of the resistance. Attached to the beam arm was a Y-piece that had at its other end a bow-shaped springy metal brush that pressed upon the commutator.



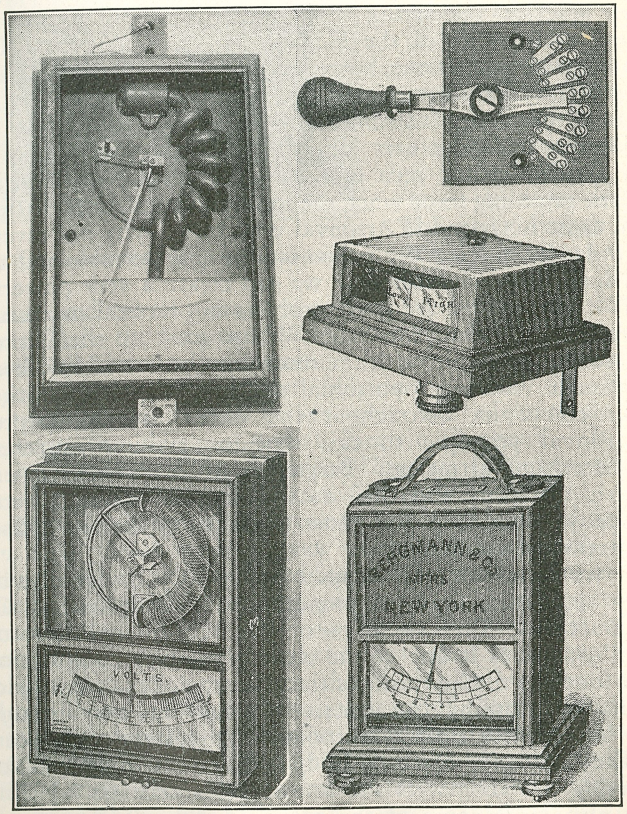
Edison walking beam automatic pressure regulator, made by Bergmann & Co. (Now in the Edison historical collection at Dearborn.)

When under the action of one or the other operating electromagnet, this bow would be moved in one direction or the other on the commutator and would throw in or out the regulating resistance, according to the contact closed by the relay. The colored lamps served as a further safeguard for the attendant to notice if through any cause the apparatus failed to operate.

This apparatus proved an efficient and economical method of automatic regulation and was used in numerous isolated Edison plants in America and Europe. In 1883 Bergmann & Co. began to manufacture the Edison ammeter and volt-

meter. These pioneer instruments included a curved soft iron wire that swung on a pivot like a pendulum and was attracted into a similarly curved coil of wire when a current passed through it. They were crude and rugged, and gravity acted as a retarding force. Ammeters were made in many types, ranging from 1 to 2,000 amperes; the Edison direct-reading pendulum voltmeter read up to 100-110 volts, and others with double scales gave readings to 200 and 300 volts.

Edison also constructed a neutral pendulum ammeter that was placed in the neutral or middle wire in the three-wire



Edison pioneer ampere and voltmeters made by Bergmann & Co. (Now in the Edison historical collection at Dearborn.)

system plants. These instruments indicated which side of the three-wire system was out of balance.

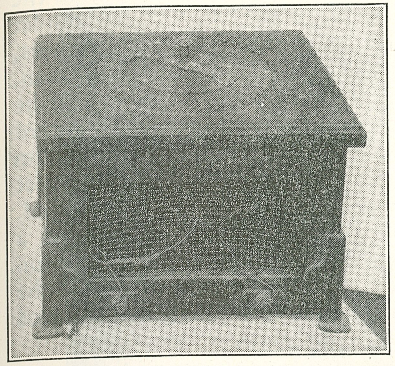
Often when I look back to those first years, I wonder what retarded our devising better measuring instruments of a practical kind. In England Sir William Thomson had already brought out his volt and ampere instruments, and even before then we had the Deprez fishbone galvanometers, which came out in 1880. With an improved model that the French Edison Company of Paris sent me in 1882 I regulated the tension of the Brunn Theatre Edison plant in Moravia, Austria—now belonging to Czechoslovakia. At that period other practical measuring instruments appeared in Europe, among them those of the Messrs. Ayrton and Perry. The great turning point came, however, when the Deprez-D'Arsonval principle became recognized as the standard for nearly all kinds of measuring instruments of the 'dead-beat' kind.

Deprez made the first 'dead-beat' instrument having an iron needle held at zero in a strong magnetic field which was the retarding force when the instrument was in operation. Then came his friend D'Arsonval who said, 'Why not reverse the order by making the galvanometer coil movable and the iron stationary; in this way we can create a very powerful field?' That solved the great problem in practical measuring instruments. Some years later Weston took up the Deprez-D'Arsonval principle with the result that at last a 'dead-beat' instrument with a proportional scale came on the market. Other companies throughout the world use the Deprez-D'Arsonval principle to this day for making ammeters, voltmeters or wattmeters. Bergmann & Co., Edison General Electric Company and their successors, the General Electric Company, continued for some years to make the Edison ammeters and voltmeters.

It would extend this chapter too greatly to describe the many accessories that the pioneer firm of Bergmann & Co. manufactured. Their catalogue of 1883 with its copious wood-cut illustrations is one of the most interesting compilations to be found in the literature of the industry. It is a historical document recording the genesis of a new industry brought into being when Edison introduced his system of lighting.

They made Wheatstone bridges, Thomson high and low reflecting galvanometers and astatic galvanometers. I think they also made some of the current pressure indicators invented by John W. Howell, veteran incandescent lamp

engineer of the Edison Lamp Factory, later the General Electric Company. They manufactured many kinds of resistance boxes for generators and feeder lines. They made small fan motors and, in fact, an endless variety of things that came up as experience dictated. It was Bergmann & Co. that in 1881 brought out the insulated paper tubes used in wiring and developed with them a complete system of connections; these were later covered with metal. Today that system is known as the interior conduit one.



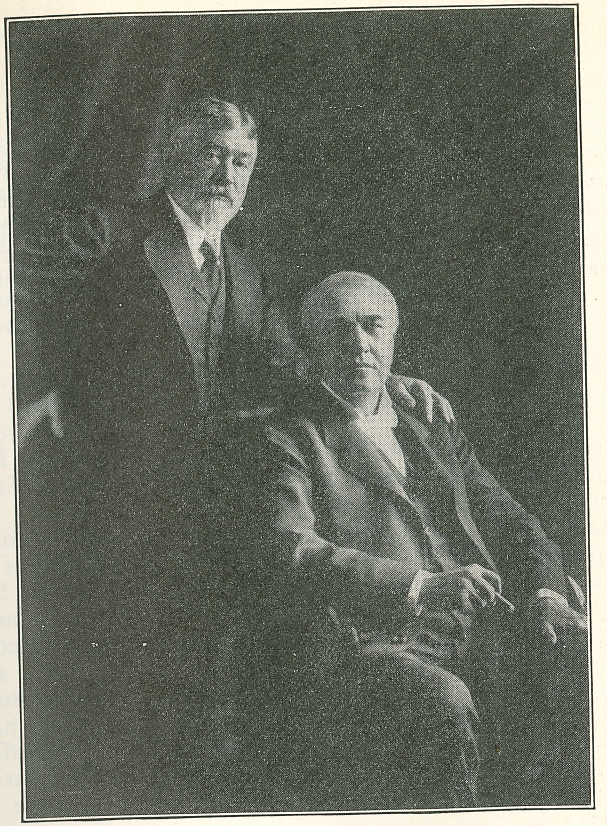
Edison pioneer regulating resistance box.

Bergmann & Co. made the accessories for the great French Electrical Exposition of 1881 and for all the Edison plants in different parts of the world for years. All through the eighties the Bergmann factory continued to supply the demand for electrical equipment. In 1889 this organization together with the Edison Machine Works, the Edison Lamp Works and some others were merged into one large concern, the Edison General Electric Company. In 1892 that company and the Thomson-Houston Company consolidated into the General Electric Company.

Sigmund Bergmann's career like that of Sigmund Schuckert, both of whom were once workers at the bench in the Edison factory at 10-12 Ward Street in Newark, forms another instance of inherited sterling qualities that led their possessor successfully through life. As Bergmann was one of the stars in the Edison galaxy of the days when the master began to put into practical shape the results of his creations at Menlo Park, I shall here outline some of the main events of his extraordinary life. His valuable assistance to Edison is interwoven with the beginnings of the gigantic industry. Those of us who knew Bergmann respected and appreciated his friendship, for he was a congenial and sympathetic character, with an ever jovial optimism.

He was born at Dennstadt, Germany, on June 9, 1851. As an immigrant mechanic he came to America in 1869 and was soon engaged by Edison at the Ward Street factory. When Edison moved to Menlo Park in 1876, Bergmann went to New York City and opened a small shop with one man and two boys at 104 Wooster Street. Intrusted by Edison with the manufacture of his inventions, he moved in 1879 to ampler quarters at 108-114 on the same street. In these new quarters, where power was also rented, he gradually increased his men, and in 1881 had more than fifty working. In that year he associated E. H. Johnson with himself, and afterward Edison was taken into the firm. In 1882 the firm of Bergmann & Co. moved into a large six-story building at 17th Street and Avenue B, and soon several hundred men were employed. In the same building on the top floor Edison installed a laboratory for himself. An annex was rented for Bergmann & Co. at 27th Street and First Avenue. Then in 1889 all the Edison interests, including that company, were consolidated

Factory of Bergmann & Co. at Seventeenth Street and Avenue B, where equipment used in first installations of Edison's lighting system was made.



Edison and his ally, Sigmund Bergmann, in Berlin, 1911. Bergmann was a valuable asset to the Edisonian cause.

into the Edison General Electric Company under the leadership of Henry Villard. It had a capital of $12,000,000.

'It might appear strange on the surface, but one of the reasons that most influenced Edison to regrets in connection with the "big trade" in 1889 was that it separated him from his old friend and ally, Bergmann.'(1)

(1) Dyer & Martin, *Edison, His Life and Inventions*, Page 748.

Yes, old-timers knew well that Bergmann was a great ally of Edison, and there was no one in those wrangling commercial business days toward the end of the eighties in whom Edison had more confidence than Bergmann. Bergmann's abilities as a manufacturer, pioneer designer and executive were always at Edison's disposal and his supporting loyalty to his former chief was more than genuine. As one of the partners of Bergmann & Co., Edison once said: 'Among all the men I have had associated with me, he (Bergmann) had the commercial instinct most highly developed.'(2)

The company was a successful money-making concern until those changes in 1889 that ruptured the business ties of these two friends who had been united nigh on to twenty years.

Bergmann was then free but did not stop his work. In 1890 he started the Bergmann Electric and Gas Fixture Company at 527-537 West 34th Street. After this venture he started the Incandescent Arc Light Company at 572-578 First Avenue and 33rd Street. In 1895 he sold his 33rd Street factory to Samuel Insull.

Back in 1891 he had organized the 'Bergmann Conduit Company' in Berlin. Philip Seubel was in charge of his conduit German works while he, having returned to New York City in 1892, was organizing the 'Electric Equipment Company.' In 1893 he organized the 'Bergmann Electric Motor and Dynamo Company' in Berlin. In 1895, after selling out his American interests, he returned to Germany and in 1900 consolidated his German factories under the name of 'Bergmann Electrical Works.' Success crowned his efforts and his works soon acquired an international reputation, vying with those of the General Electric, Westinghouse and others.

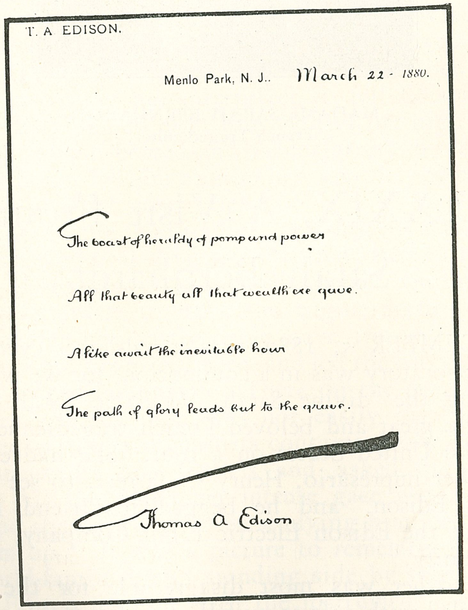
I paid him several visits during the years before the Great War, and was astonished at the magnitude of his undertaking. At times more than thirty thousand men were employed in his works. He manufactured everything in the electrical and allied line and his products went to all corners of the world. He also manufactured steam turbines and everything for the complete equipment of central stations and power transmission.

Bergmann was one of the greatest personalities associated with Edison. His initiative and skill in putting Edison's

(2) Dyer & Martin.

early ideas and inventions into practical commercial form created an industry that is still growing and in the history of that art his name leads the list. He was a keen business man, possessing vision and acute organizing and executive ability, and his engaging personality endeared him to all. He passed away on July 7, 1927, in Berlin.

In Germany Bergmann received many honors from universities and from his government. He held the titles of Doctor of Engineering and Privy Councilor. Such was the senior partner of Bergmann & Co., Edison's ally in pioneering manufacturing days.


T. A EDISON.

Menlo Park, N. J.. March 22 - 1880.

The boast of heraldy of pomp and power

All that beauty all that wealth ere gave.

Alike await the inevitable hour

The path of glory leads but to the grave.

Thomas A Edison

In Edison's handwriting. From Gray's 'Elegy Written in a Country Churchyard.'

MADAME SARAH BERNHARDT
French Tragedienne.

LXXIX. A Visit From Sarah Bernhardt

DECEMBER 5, 1880, was a red-letter evening. The laboratory was in a commotion, for we were expecting the 'divine Sarah,' Madame Sarah Bernhardt, the great and beloved French tragedienne who was then in the United States on a tour. She had expressed a desire to her impresario, Henry C. Jarrett, to see and know 'Le grand Edison,' and he begged his friend Robert L. Cutting, of the Edison Electric Light Company, to arrange an opportunity.

The weather was most disagreeable for the occasion. Rain mingled with soft snow fell steadily, making the roads muddy. All who could, remained indoors. However, weather could not hinder Sarah.

'I don't think she will come on a night like this,' Upton

remarked, and a discouraged look came on some of our faces, for we were all anxious to see the 'greatest' woman of the age.

Suddenly Johnny Randolph ran in, informing us that a telegram just had been received from Cutting stating that the party was leaving the Jersey City Pennsylvania Depot on the 6:35 p. m. train. A sigh of relief came from all, and we patiently waited for the train whistle as it approached our tiny hamlet.

Cutting afterward told Edison that on the way down Madame Bernhardt asked many questions about him and even went into most inquisitive details. 'She wanted to know if you were married,' he added, which made Edison blush.

Edison had sent his carriage to the station and all that could get in rode. Those that could not get into it had to plough through the mud to the office building. There the party, consisting of both ladies and gentlemen, was received by Edison in the library. Most of us were not present at the time, but we were told that when Edison came forward to greet her the expression of his face and eyes betrayed his great interest. They shook hands warmly, and then Madame Bernhardt instructed her interpreter to tell Edison she was more than delighted to meet him, and of her high esteem of his genius. Edison bowed and asked Jarrett to reply that it was a great honor for him to meet her, and that he had always admired her and her great talents.

'Merci beaucoup,' she replied, pressing his hands fondly. Then Edison's natural shyness reasserted itself as he realized the crowd about him. He excused himself, murmuring that he must give orders to have the engine started, an order which some one else easily could have transmitted.

In a few moments he returned, and led the party downstairs and across to the laboratory. There on the ground floor he showed her around. She was not easily rushed through. She stopped at the two cabinets containing old Edison telegraph instruments and models and asked question after question. All the while her intense gaze was centered on Edison, and she appeared to be studying him, or, as we say, 'sizing him up.' It was a picture to remember—those two young world-famed figures standing side by side.

When Edison finished with the instrument cases he lead the way to the testing table where I was stationed, keeping control of the tension at the wheel.

'Turn it down, Francis,' he told me.

As the lights slowly dimmed, Sarah Bernhardt was full of expressive curiosity. Then Edison ordered me to 'turn it up,' and as he directed her to look out of the window, she saw the starry lights in the fields slowly increase in brightness. She was enraptured. She wanted to try it and Edison winked at me in acquiesce. She did not jerk the wheel around impulsively, but handled it as I had. When she had turned the lights down and up, she let go and clapped her hands in joyous satisfaction.

I watched her—a fine, delicately-proportioned figure, slender and a striking contrast to the Gibson girls of those days. Her face was impressive, having a sharp and well-defined contour, while the head was crowned with a luxurious crop of dark hair. In looking at her I imagined I saw the face of Cleopatra. Her eyes were life itself, fascinatingly expressive, full of piercing intelligence and luring attractiveness, which at times seemed to be but the outposts of the soul itself. She was wrapped in furs and her dress was chic.

In contrast was Edison, smooth-shaven, with his silk black cap cocked a little to one side and a small ringlet of hair protruding at the center of his forehead. He too possessed a sharp, well-delineated countenance. There was no doubt that he made a deep impression on her for there was hardly a second when her gaze was not riveted on his shy, yet resolute mien. Later in her 'Memories,' she wrote:

'I looked at this man of medium size, with rather a large head, and I thought of Napoleon I. There is certainly a great physical resemblance between these two men, and I am sure that one compartment of their brains would be found to be identical. Of course, I do not compare their genius. The one was destructive, and the other creative.'(1)

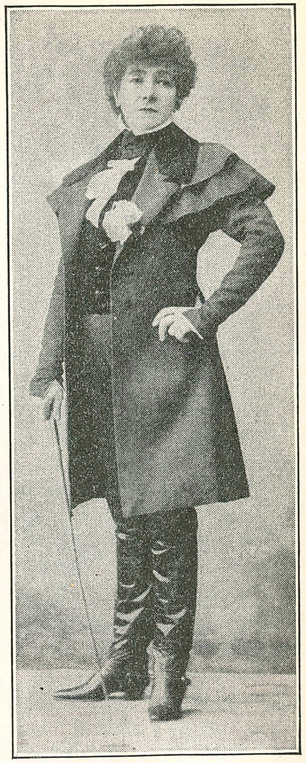
I had one of the portable models of the electric lamp with the wooden base, and she was enchanted with it. She took it up, turned it in all directions and touched the bulb. She matched the colors of her dress, lifting it up with a swing —in those days ladies wore long skirts—and in all her movements there was a dexterity that was charming. She asked Cutting, who also spoke French, and was always a first nighter at the theaters, when he would introduce the light in Paris, for she must have it in the theater and at home.

'C'est grand, c'est magnifique!' she cried, and then ex-

(1) See Volume 1, Menlo Park Reminiscences. Page 232-3.

plained that the light was pure, it was steady, it was clean and not hot. Fixing her eyes again on Edison, she eulogized his achievements. By this time he had become accustomed to her sincere adulation, and he appeared bolder and more at ease in showing her around. She manifested a special interest in the dark black room where the Bunsen photometer was located. No doubt she thought of some scene in a play in which a catafalque stood, for she remained there a few moments in silence, as if in contemplation.

Then Edison led the way to the ore essaying room and explained how the first successful filaments were carbonized. Leaving the laboratory, Edison gallantly offered Sarah Bernhardt his arm and escorted her through the sleet to the machine shop, the party following. I left the wheel at the testing table and followed, with some of the boys, for we were all thrilled with the great French actress and did not intend to let her out of our sight.


Sarah Bernhardt in 'L'Aiglon,' as the Duke of Reichstadt.

In the machine house her interest was not abated. In fact she went everywhere, picked up things, soiled her gloves and, of course, fired volleys of questions.

When Edison took her to the annex where the dynamos were running, she seemed more inquisitive than ever. How the sparks from the commutator brushes interested her and how she gazed at Vail when he shifted the brushes! She saw that he wore no gloves, so she took off a glove and touched the brush. Edison feared that her dress might get caught in

a belt, for she moved about and went everywhere, even between the narrow rows of dynamos.

Edison then had a piece of iron wire placed between the mains and when the circuit was completed the wire got instantly red, white, and then fused, sputtering incandescent molten globules over the floor. That was the kind of action and results that suited Sarah's temperament—she was transported into a state of rapturous bewilderment. She picked up a globule as a souvenir and asked dozens of questions.

Sarah's inquiries were not just idle feminisms. She, like Edison, was endowed with that great virtue called 'common sense,' and her questions were full of meaning. She was intensely interested in the dynamo machines and the magnetic force of the pole pieces as Edison showed her how they attract large bars of iron.

Edison also was interested in her clear perception and vivacity. He once said that 'She was a terrific rubberneck,' but one had to know Edison well to understand what he meant, about whom it was said, and the occasion. He highly estimated her qualities and sagacity, and was convinced that she deserved the adoration that the world bestowed.

Edison then led her to the little glasshouse where William Holzer, superintendent of the Edison Lamp Works, was requested to show her something of the glass-blowing art.

Here, as everywhere else, her manifested interest in glass blowing was as apparent as was her surprise, for glass blowing was still a rarity at that period. She would dart from one side of Holzer to the other at the glass-blowing table, watch his face and how he manipulated the glass when soft, and ejaculate words of astonishment at his dexterity.

Impulsively she grabbed Edison's arm in leaving the glasshouse, and he led the way again to the laboratory and upstairs. By this time both seemed good friends, as if they had known each other for years. The sight of the regular Edison laboratory on the second floor was for her the crowning effect of the evening and Edison had wisely arranged it so.

She was stupefied for a moment as she gazed around on all sides and saw the innumerable bottles full of chemicals, instruments and physical utensils.

For her theatrical intuition and imagination, the laboratory was a revelation that completely transported her into

the higher realms of her profession. You could see by her countenance that the scene before her was inspiring and no doubt she visualized herself in some mystic role with Edison in these surroundings.

Sarah Bernhardt as Phedre.

'C'est merveilleux,' she murmured.

Edison then showed her his motograph telephone receiver in operation. This she wanted also in her Paris home and theater and began talking about it to some of her friends in the party.

They went about the laboratory from table to table, inquisitively examining instruments. When Sarah arrived at the organ she wondered why such an instrument was there, admitting at the same time that it was really not out of place. She tried a few notes while I pumped.

The last thing that Edison reserved to show her was the phonograph and with it the climax was reached. Edison talked, sang and whistled into it and then made reproductions; he made composite records, that is, impressed other words on a record already made.

Sarah Bernhardt was jubilant. She laughed, talked, stamped her feet and clapped her hands in glee. When asked to say something into the phonograph she recited from 'Hernani' and 'Phedre.' She was elated to hear her own voice and told Edison that she wanted the phonograph to

Sarah Bernhardt talking into an Edison phonograph in Paris.

take with her—she must have one! Edison promised to have one made and sent to her, for he could not let her have the one in the laboratory.

She gave Edison a pleading look and with a gentle smile and nod he said: 'She will have one in Paris before she gets home.'

I may mention here that the others in the party were kept busy following them about. It must have been a strenuous evening for them, especially for those that also acted as interpreters. Sarah wanted questions and answers interpreted without much delay. When they were about to leave, she again paused and took a last look at the famous laboratory where that young man, who was standing at her side, had created so many useful wonders.

I still remember that scene. There was Sarah Bernhardt and Thomas A. Edison. The party was silent out of respect for the pensive mood in which the great French tragedienne had fallen. She seemed fascinated and in the mellow glow of the newborn light that this young man had given to the world, she contemplated in reflection, a picture for a master painter.

Miss Bernhardt, Edison, Jarrett and Cutting were then driven to Edison's home and Mrs. Mary Edison was introduced to the great French woman. She was congratulated on having such a famous husband and compliments were showered upon one another.

They were then taken to the station to return to New York City.

Later, when Sarah Bernhardt was at home, she sent Edison two paintings of her own.

Her visit to Menlo Park was a memorable one, and will always be recalled in Edisonian history in connection with other great and celebrated personalities who once honored us there.

Courtesy, Henry Price Ball

EDISON in 1882.
A drawing dated January 15, 1882,
by James E. Kelly.

New York City Hall and New Courthouse. (From an old print.)

LXXX. Entertaining the New York Aldermen

ANOTHER memorable day at Menlo Park was December 20, 1880. On that occasion the New York City Aldermen came to inspect Edison's system for the distribution of light, heat and power by electricity. This had been perfected to the point where, in the estimation of his financial backers, time was ripe to bring the system to the notice of New York City officials.

The object, of course, was to pave the way for a franchise permitting the Edison Illuminating Company of New York to lay underground conductors in the streets and sell electricity for all purposes. Here again my former chief, the ever-busy Grosvenor P. Lowrey, now counselor for the Edison company, made all the important arrangements.

It is surprising to observe how many elements are required to attain success. It is like winning a battle. There must be

both a smart general and good officers and men. If any fail, failure all along the line is probable.

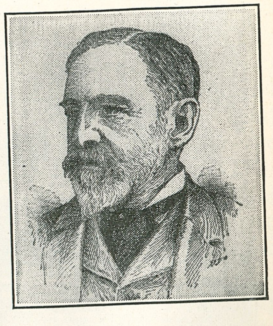
Edison had needed capital—financial aid—to have a shop and laboratory, pay workmen and buy materials. Through Lowrey, the means had been supplied.

Edison then went ahead with his job and created his new system. Although he was its creator, if he was to hold it and receive a reasonable recompense for his labors, it was vitally necessary that other capable men lend their aid.

The man who led this group was Lowrey. He generaled all the important proceedings to uphold the validity of Edison's achievements. Edison was an inventor, a scientist and discoverer, and it was only in *that* direction that he excelled. He possessed but little knowledge or experience in big business, finance, law or politics, any one of which can be a formidable help or deterrent. So it fell upon Lowrey's shoulders to marshal together the necessary forces and lead Edison's system into the domain of commerce. He was Edison's guardian angel against pirating.

At the same time he was a big factor in getting things started legally. Already by December, 1880, he had pushed the first application of its kind ever presented to a municipality. To give the City Fathers a broader idea of the subject, Lowrey arranged to bring them to Menlo Park where they could see and hear explained the details of the Edison system. They could thus form a more intelligent opinion on the matter when it was presented to the Board of Aldermen.

The date was set for December 20, 1880. At 4:30 o'clock that afternoon a special train awaited the aldermen at the Pennsylvania Railroad station in Jersey City. Other distinguished men were included in the party, along with officers of the company.



Edward Cooper, Mayor of New York in 1880, and son of Peter Cooper, the philanthropist.

Among the guests on the train were President Morris of the Board of Aldermen and such prominent members as McClave, Fink, Wade, Jacobus, Strack, Kirk and Slevin. Park Commissioners Green and Lane, and Superintendent of Gas and Lamps McCormick were in-

cluded. The Edison company was represented by Lowrey, Major S. B. Eaton, C. Goddard, Nathan G. Miller, Tracy R. Edson, F. C. Henderson and others.

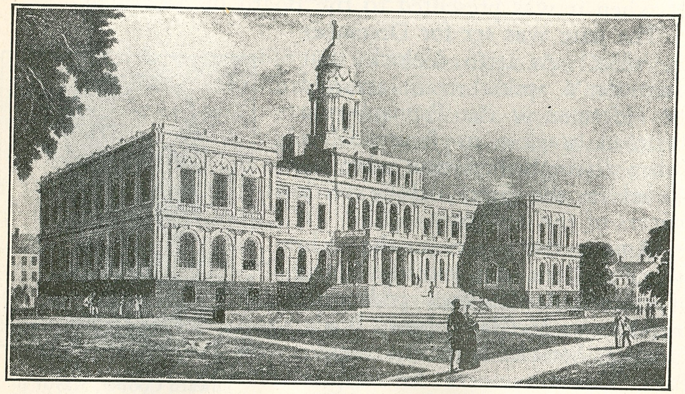
Of course cigars were passed around and the train began its journey with a very congenial group. It was amusing to see how the Republicans were fraternizing with the Tammany adherents, void of all contention.

Darkness had fallen when the train reached our little village, and all were surprised when they saw the fields lighted by Edison's new lamps.

At the office Edison was introduced to the party by Major Eaton. He shook hands with all, and welcomed them to his place. The City Fathers were amazed at the simple, unpretentious figure that Edison presented; his modesty struck them. There was no bluff about him, no protruding of the chest or inserting his thumbs into the waistcoat openings. They had imagined that the great Edison was sort of a serious person, with a professor's mien and manners.

'Why,' whispered one City Father to another, 'he looks like a regular fellow. See how he handles his cigar; just like the boys in the Wigwam!'

In fact, Edison had made an impression upon them from the start. The party was led by him to the laboratory and later to the machine shop, while he explained the most important details of his system. When the aldermen saw how



Front view of New York City Hall in 1826. (From a print in New York Historical Society.)

the lights of Menlo Park could be gradually extinguished and then slowly brought up again to normal intensity, they applauded.

President Morris remarked to Superintendent McCormick, 'That's the end of those dilatory lamplighters in New York City.'

This caused Mitchell to ask if he remembered Wood. Wood had been greatly impressed with a new sweeping machine, and they tried it in the park.

'What do you think of it, Pat?' some one asked a nearby sweeper.

'It's a wonderful thing,' said Pat, 'but, yer know,' he added, 'it can't cast a single vote.'

It was said that the Mayor took the hint. The sweeping machine was never endorsed, and the sweepers held their jobs!

Edison demonstrated the safety elements of his system, including the use of his fuse wire, and described the latter's role as a protector of life and property.

Then the talk centered on the danger of high tension series arc light wires suspended on poles along New York City streets. Edison explained how his system carried a tension of only 100 volts, and that his conductors were to be put underground.

Some one remarked that trimmers of arc lights were constantly exposed to danger. Turning to Morris, Edison asserted that the same danger existed when a high tension arc line broke and happened to fall on some one passing. He referred to several well-known cases.

The workmen of every department were stationed at their posts during this demonstration. When Edison had shown the party through the rest of the buildings, he conducted them upstairs in the laboratory. The aldermen were tired and thirsty. When they arrived upstairs there was only one lamp burning by a vacuum pump in the front part near Edison's old telegraph table. As the lamp was in the front of the board on which the pump was mounted, its light was so obstructed that the rear of the room where the organ stood was as dark as a grave.

Some aldermen grumbled about the darkness. They scarcely could see their way about. One spied the sink and said to a fellow colleague: 'How about a drink of water?' The offer was insultingly rejected.

At last, when the whole party had mounted the steps, Edison clapped his hands, the prearranged signal for me to turn on all the lights.

Presto!—the place was brilliantly lighted. Sighs of relief went up, followed by acclamations from all sides. The laboratory of the wizard of Menlo Park, with its instruments and chemicals, appeared before them. At that instant they were momentarily dazzled with the scene, but as their eyes turned toward the rear of the laboratory, every face began to beam. Their spirits rose, their tiredness disappeared, smacking of lips was audible.

They saw long tables arranged in horseshoe fashion and decked with a spread such as only old New Yorkers could describe. There were dainty comestibles from the larder of the most famous chef in America, and wines of the rarest vintage, as well as choice Havana cigars. Waiters, dressed immaculately in swallowtail coats and white gloves, stood ready to do their duty. The famous Delmonico was the caterer, and Lowrey, who not only excelled in jurisprudence but was also well known as an epicure, had arranged the menu. When Lowrey made up a menu, the jadest appetite was revived and craved for the dainties he selected.

It isn't any wonder that when the aldermen had sized up the display on the tables, their appetites and eyes were sharpened. Lowrey knew what he was doing; he followed the wise maiden's admonition to win a man through his stomach.

Cartoon from *Truth* showing aldermen at Menlo Park repast.

Lowrey sat at the head of the table and presided, with Edison at his side. Soon only the clatter of dishes, knives and forks and glasses was heard. It is always good policy to permit guests to enjoy their meal and to defer talking until the dessert course. By that time the aldermen were in animated spirits. Then Lowrey arose and

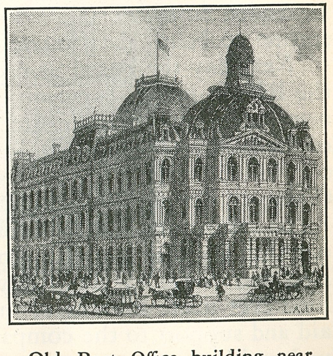
delivered a speech. First he complimented the mayor as the head of the great metropolis. He complimented the Common Council for its vision, foresight and ability to grasp any situation that furthers the interest and progress of the great city it represented. His laudatory words caused some of the City Fathers to pull down their vests and assume an important look, while others applauded. Then Lowrey began with a Ciceronian discourse on Edison, speaking of the obstacles that Edison had overcome to win final success. He, the poor boy who had taught himself, had succeeded in giving the poor as well as the rich a new, healthier light, he said.

Lowrey next described the difference between the arc and incandescent light, and the safety factor of the latter. He went into details as to its simplicity, cheapness and sanitary qualities.

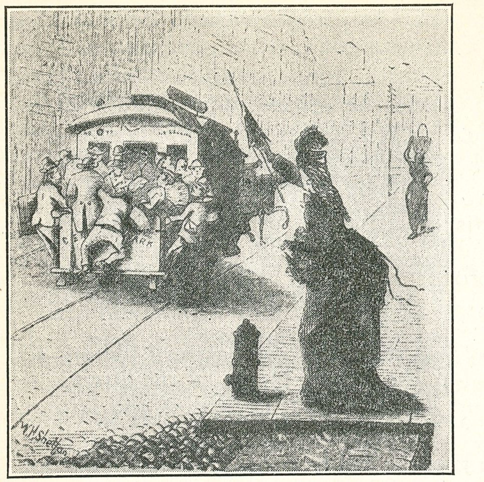
When he had finished he held up his glass and proposed the health of Edison. All joined him and they drained their glasses. Between the popping of corks, more healths were toasted.

About that time all wanted to talk at once, but President Morris, looking sharply at his colleagues, said he would speak for them as well as for himself. 'It was,' said Morris, 'a source of great gratification to them all.' The inventor was entitled 'to the thanks of the world for bringing this light to such perfection that it now can take the place of gas.' He then thanked Edison in the name of the Board of Aldermen of the City of New York for the great good he had accomplished. Again the glasses clinked and promises were heard that their votes would go to Edison when the matter came up formally.

While some of the City Fathers were unbuttoning their vests in order to breathe more freely, McCormick gained the floor. He lauded Edison and Menlo Park, and spoke like Demosthenes. I



Old Post Office building near City Hall Park, New York City.



Cartoon of old belt line horsecar in New York City.

noticed that Mackenzie's eyes were wetting and I asked him why. 'Don't ye hear how he rolls his r's? Ain't that enough? He's a brother.' Mackenzie took more consolation and felt better.

And so it went. Speeches were made by Park Commissioner Lane and Alderman McClave. The latter said he was a disciple of Progress and was vociferously applauded by Mackenzie as a 'brother.' Henderson, chief engineer of the Oregon Steamship Company, told how successful the Edison light had been on the Steamship *Columbia* during its maiden voyage several months before. All agreed that the system was a decided success. Some one proposed three cheers for Edison. The three rousing cheers that followed made the walls of the laboratory shake. They were followed by the last of the sparkling beverage. Hands were shaken and slowly the party descended from the laboratory and returned to the railroad station to board their train for the return home.

Next day the Board of Aldermen met at the City Hall and the Edison matter came up. Many of the aldermen, so the newspapers reported, regaled themselves with reminiscences of the pilgrimage. Major Robert Taylor gave each a printed copy of the resolution which the Edison Electric Illuminating Company desired the Common Council to pass.

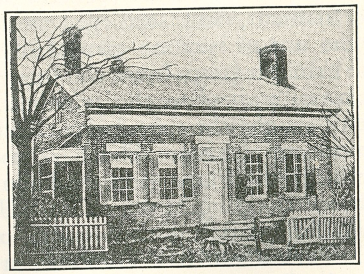
In asking for the franchise the Edison company pointed out that the creation of a central station for supplying light, heat and power by electricity was the first proposition of its kind ever made anywhere, and hoped the council would give aid and support to the company starting such a revolutionary undertaking.

Of course when the aldermen began to consider the proposition, they were aldermen of the City of New York again. The Delmonico dinner was already digested, the beverages evaporated, the Havana cigars gone up in smoke. Seriously they discussed the matter and handed it over to the legal department for an opinion.

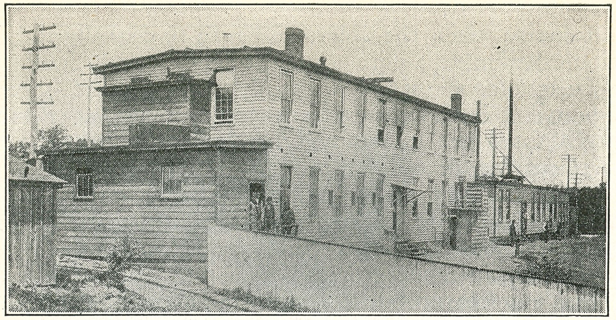
Things did not go so fast as we expected. Plenty of wrangling and wire pulling followed before the company received the franchise that permitted them to tear up the streets and place underground conductors in position.

'That's a fine proposition that the New York Board of Aldermen wants us to accept,' remarked Edison in January, 1881. 'As you know, we are going to place our conductors on both sides of the street and they want to tax us ten cents per lineal foot and that would be, if we lighted the whole city, about $400,000 a year! Then after three years they want to put another tax of three per cent on our gross receipts. If we were in a stock-speculation game it would pass, but we are an honest company doing serious work and starting a new industry that will find universal applications.'

However, the soup is never taken as hot as it is cooked, and through the energies of Lowrey, the Edison company at last succeeded in obtaining conditions that, under the circumstances, made possible commencement of the work.



Birthplace of Edison at Milan, Ohio.



World's first incandescent lamp factory, Menlo Park, 1880.

LXXXI. The Lamp—Beginnings of Manufacture (PART ONE)

AT MENLO PARK, New Jersey, the first incandescent lamp factory in the world was installed and operated on a commercial basis.

Incandescent lamps used during the first demonstration of Edison's system during the winter of 1879-80 were manufactured at the laboratory, as I have said.

During the months while these demonstrations were under way, Edison worked on the problem of improving the quality of the filament, and succeeded in making a more stable one by the use of bamboo instead of paper. Experiments with the bamboo lamps were conducted at the laboratory for some time, and when the principal obstacles were subdued, Edison thought the time had arrived to start manufacture on a commercial basis. This was about the middle of the summer of 1880. Plans were made to utilize the old neglected clapboard building in which he had once made his electric pens.(1) This building was situated on the southeast corner of Menlo Park about half a mile from the laboratory grounds, across the Pennsylvania Railroad tracks.

During 1879, I often strolled over in the evening to this building. It fascinated my romantic soul because in it the Edison Electric Pen was once made, the pen with which I

(1) See Volume 1, page 94.

was so familiar, and which I operated before I joined Edison. When Edison passed over its manufacture to the Western Electric Company of Chicago, the building stood unoccupied for a few years.

I say it was unoccupied, meaning for any legitimate purpose; but it served as a night shelter to bands of weary hobos who were 'pounding' the road between Jersey City and Philadelphia.(2)

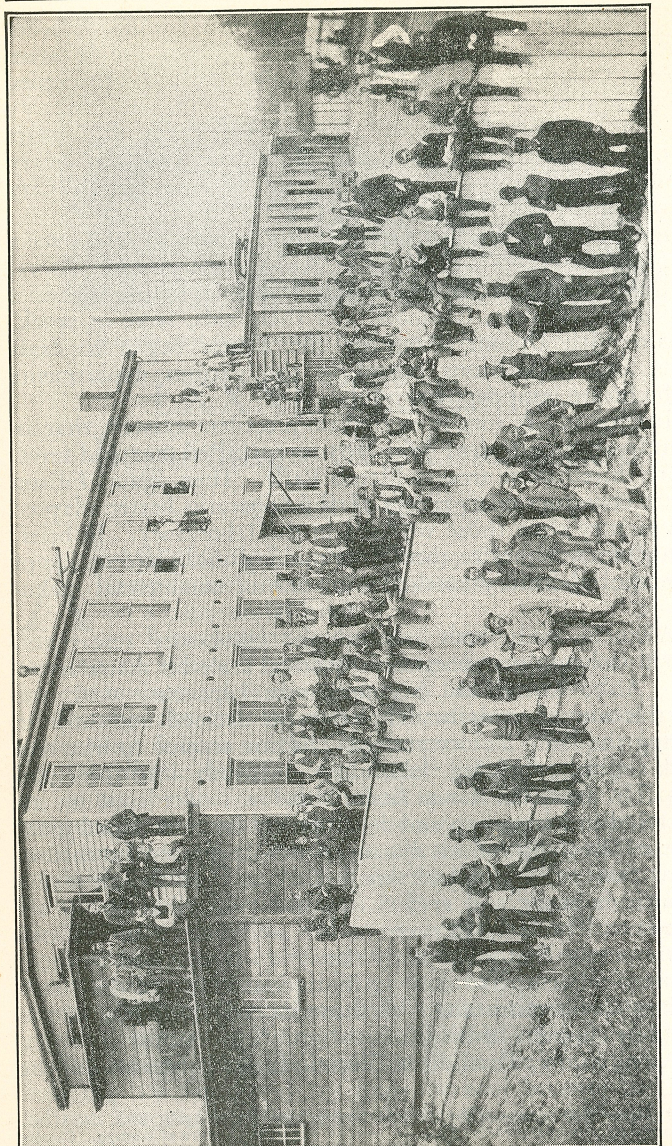
Edison's first move to fix this building was to send over a gang of carpenters and make it tenantable, as roof, floors, etc., were all in a dilapidated condition. While Kruesi's carpenters, Moffett, Campbell and their aids, were at work, Edison with Upton, Batchelor and Kruesi began to draft plans and dispositions regarding the various departments of the future lamp factory.

It must not be forgotten that no precedent existed, that an entirely new art had to be taught to unskilled men and boys, mostly hired from around Menlo Park. Then again, Edison had to construct many pieces of new apparatus better adapted to a factory than those we used in the laboratory. In brief, he had to systematize the art of making incandescent lamps from the laboratory method into one of commercial manufacture.

After he had about finished the laboratory researches, he had to begin new ones on a practical scale for manufacturing. Also, Kruesi and his men were kept busy with the construction of utensils and apparatus deemed necessary in getting the lamp factory started. Edison seemed to like this work of transforming laboratory methods into practical ones. In fact, the lamp factory had a tender spot in his heart and in its growth and development he entertained great hopes. The lamp and his dynamo were his greatest inventions up to that period, and he knew that in their future was a gigantic industry and system of current distribution for all purposes. The lamp factory was his pet hobby; he visioned it as a purely Edisonian affair always to be retained as such. The work that he had done in that connection and the recollections and reminiscences of those days formed one of the brightest chapters of his life.

As we know, The Edison Electric Light Company was the

(2) When Edison moved the lamp factory to Harrison in April, 1882, the Menlo Park building was abandoned. It again became the headquarters of tramps. Finally they set it on fire, and it was destroyed.



Menlo Park incandescent lamp factory, summer of 1880. The four men in the center foreground are Philip S. Dyer, William J. Hammer, Francis R. Upton and James Bradley. The carpenter holding square (fifth from left) in front row is H. A. Campbell. Sitting on rail at open shed door (in gray suit): William Holzer.

parent, with control of all Edison's electric light patents. That company did not desire to enter into manufacturing, but wished only to grant licenses. In its contract with him, he was obligated to sell his manufactured products at a certain price, from which the company received a part of its royalties.

So it happened that Edison with Batchelor, Upton and Johnson raised the money to install the first incandescent lamp works. Edison, of course, had the controlling interest, about 80 percent; his share was greater than the combined shares of the others.

Edison, Batchelor and Upton were the active members who devoted their time in building up the lamp works, while Johnson was the outside man. He was active at that period in pushing the Edison system in England. Where did they obtain the money for this investment? Well, Edison had received a certain number of shares from the parent company for his work in creating his system. He in turn distributed some of these to his loyal assistants, and as the shares stood very high on the market at that time, some were sold. From the proceeds, the capital was procured to set up the lamp works. It also was said that some of the money Edison received for his European telephone patents was invested here.

After Kruesi's carpenters had set the old building somewhat in order, it was divided into different departments, and ways and means were sought to make each as efficient as possible. Of course, Edison knew that as time went on many changes would take place in the process of manufacturing. The problems of first importance were the processing of the bamboo, the carbonizing outfit, and setting up an efficient glass-blowing and vacuum pump department.

The necessary power for operating the various motors, etc., was to be otained from the laboratory machine shop on the hill. The line was erected by Hammer and Force under the supervision of Upton.

During the day two of the dynamos at the laboratory machine shop were connected in series, while another supplied current for the field magnets. At the lamp factory, the power was used by electric motors which drove the blower for glass blowing, in the carbonizing furnaces, for rotating the glass annealing machines, by the saw which cut up the bamboo, for lifting mercury in the pump room and for lighting and testing purposes.

The laboratory machine shop continued to deliver current to the lamp factory until March, 1881; then Edison built a separate power plant at the factory. A house was erected, and a steam engine and boiler were installed. The former supplied power for driving six Edison dynamos, and the current thus generated supplied the motors, lighting, etc. Steam from the boiler was used also for heating purposes.

It may be mentioned that the transmission of electric energy from the laboratory machine shop to the lamp works in 1880 was not only unparalleled at that date, but historically it was the first example of a commercial factory using solely electrical power in its operation. It demonstrated the Edison system for the transportation of light, heat and power.

The lamp factory was also equipped with a large gas manufacturing plant for use in the glass-blowing department, and in the carbonizing furnaces.

As has already been stated in the chapter on Bamboo, the best quality had been discovered by Moore in Japan. Near the Iwashimizu-Hachiman-Gu shrine in the Kyoto Prefecture, Moore found the bamboo that Edison considered best for his filament. At first when the bamboo arrived at Menlo Park, it was placed in a storeroom, sawed into the required lengths, and later split up gradually into splints. The splints were then planed down to a ribbon, after which they were cut out in separate apparatus into raw filaments. The reader may have noted an illustration of the gradual splitting down of the bamboo, working it into a raw filament.(3)

It must not be forgotten that Edison, Upton and Batchelor went to great pains in instructing unskilled labor in the art of working the bamboo into filaments. At the same time Kruesi had to make and devise many of the small bamboo planers and apparatus with knives, for cutting it down. Of course, in order to obtain systematic results, gauging apparatus was also used. It must be evident that the starting of the work in the various departments, getting them into an operative condition, was a difficult and tedious task, requiring infinite patience. After that, when everything was set going, it was much easier to improve the apparatus and system of procedure whenever necessary.

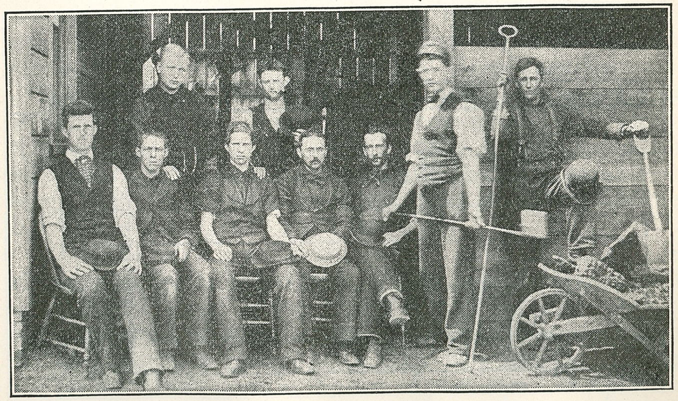
After the raw filaments were finished, they were passed on for carbonization. That system also passed through

(3) Chapter LXIX, pages 628-9.

many changes. The first bamboo filaments had been cut out with shanks at their ends so that more surface contact was obtained when they were inserted into the platinum or nickel clamps. These first clamps also had a tiny screw to tighten the contact surfaces of the clamp and carbon shank of the filament, and thus make a better contact. This operation was expensive in more than one way, the metal was expensive, the making of the delicate clamps and screws was costly, and many carbon filaments were broken when they were inserted into the clamps.

Edison remarked that the shanks on the carbon filaments were an expensive affair, and that we must try to get rid of them. He knew the small clamps were not ideal for contact making, and for that reason devoted much thought to the subject at the laboratory. The filaments with shanks were also expensive in another way. In carbonizing them, each filament was put into a separate small mould. At first iron moulds were tried, then Edison made them of nickel and plumbago. Later he tried some of fire-clay.

However, the nickel moulds were the ones we used when the Edison Lamp Works were first started, and were the ones to receive the most attention at the time. Large numbers were fabricated. Costly also was the process of placing the raw filament in the mould. The outside dimensions of



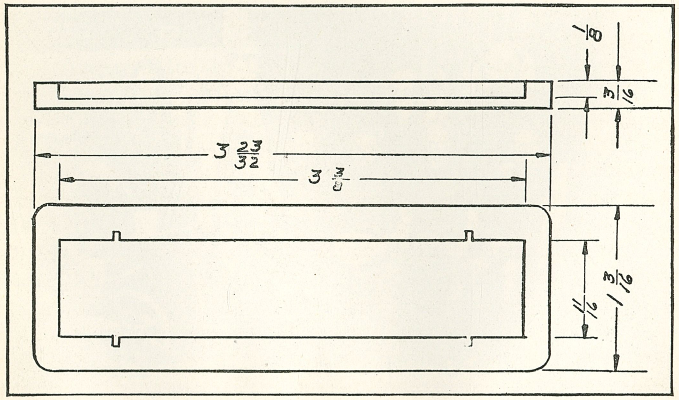
Carbonizing squad at first lamp factory. Luther Smith, Robert White and Alex Welsh are in the group. Smith has foot on wheelbarrow.

these nickel moulds were as follows: length 3-23/32 inches, width 1-3/16 inches, and depth 3/16 inch. They were hollowed out in an oblong fashion, having a length of 3-3/8 inches, width of 11/16 inch, and depth of 1/8 inch. The ends of the mould on the outside were rounded. Edison was particular at that time to have the carbonized bamboo filaments appear neat and straight; that was one reason the raw bamboo filaments were carbonized individually, each in a nickel mould and kept straight during the process of carbonization by having guide pieces inside the mould as shown in the illustration on page 618.

The mean shrinkage of the bamboo filament was about 25 percent during the process of carbonization. The nickel guides in the mould permitted this, and at the same time kept the filament legs straight.

As already mentioned, the preparation of the bamboo raw filament was costly because it was necessary to cut out the shanks at the end of their legs for contact purposes. Without the shanks, the finished raw ribbon of bamboo could have been cut up into more than one filament.

Then again, the raw bamboo filament had to be bent into a hairpin form. In taking account of the grain, the shanks came at right angles to its legs, and this prevented placing more than one filament into the little nickel carbonizing mould. After each filament was individually carbonized in a mould,



Dimensions of nickel carbonizing mould. Pictures of mould and guides are on page 618; nickel moulds may be seen at the Edison Laboratory at Dearborn.

the moulds were piled one upon another and placed into a large plumbago container packed with carbon dust. The container was then inserted in the carbonizing furnace. Incidentally, the moulds had no covers, but were simply piled one upon another like a pack of cards.

In order to prevent any rupturing of the grain of the wood, the raw filaments were at first steamed and later on a hot burnished round iron was used to bind them over.

Edison, of course, was well aware of these various disadvantages, but a start had to be made, knowing that time would soon bring many improvements.

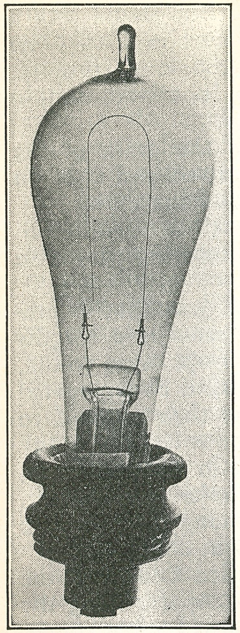
Another disadvantage shanking caused was that it prevented the sorting of the carbonized filaments into lengths for voltages. Thus, when the finished lamps were tested, they varied in voltage considerably and had to be segregated into lots of different voltages. They were then supplied to different plants which operated at different voltages. Many of these obstacles were soon obviated, for in the same year, 1880, Edison commenced to plate the shanks with copper, thus making them rigid and thereby reducing the breakage when inserting them into the tiny platinum clamps.(4)

The copperplating of the shanks soon led Edison to the idea of making a simple copper holder and copperplating the filament to the holder. The latter consisted of a copper wire, one end of which was fused to the platinum lead wire of the lamp; the other was flattened out and lapped sidewise to form a temporary sort of clamp or holder. After the filament legs or shanks were inserted into these holders, that part was placed in a copper bath and plated together.

This developed toward the end of 1880. In the early part of 1881, the Edison Lamp Works employed this system of filament attachment. In fact, the lamps used in the demonstrations of the Edison system during the early part of 1881 were of the bamboo filament type, in which the filament was copperplated onto the lamp leads.

Copperplated filament attachment continued until 1886, when carbon paste superseded it. The copperplating method resulted in a great saving in the cost of manufacturing the first pioneer commercial lamps. We saved the cost of making the tiny platinum clamps with their tiny screws, and there was considerable saving in the cost of platinum. The platinum

(4) Such lamps with copper and silver-plated shanks may be seen at the Edison Laboratory in Dearborn.

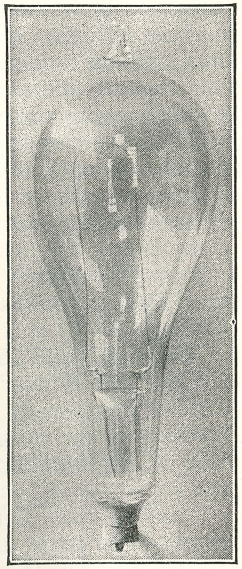


Bamboo lamp, showing platinum clamps that held filament.

leads that passed through the glass stem were gradually shortened so that by the latter part of 1881, employment of that metal had almost ceased. Thus the copperplating method did away with all platinum in the lamp except that used through the glass stem as leads.(5)

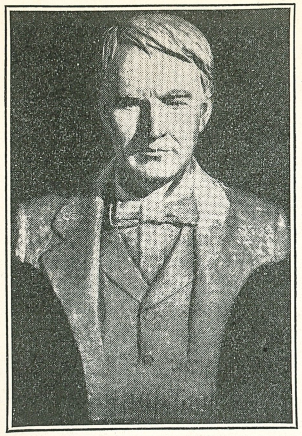
The method of copperplating was simple. It consisted merely of small wooden troughs, in the bottom of which bevel perforations were cut; bevel-shaped rubber corks with a center aperture fitted into the bevel holes; into these the glass stems with their filaments were inserted, and these were then pushed down so that the top part of the copper holders were just about immersed in the plating solution. All the copper leads of the stems were connected to one of the proper terminals of a galvanic battery, while the other pole of the battery terminated in a strip of pure copper immersed in the plating bath. The current deposited enough copper in a few minutes to insure a good contact between filament and holder.

The part subjected to the plating process was next gently rinsed with



View of lamp showing how copperplating process did away with the platinum clamps.

(5) Platinum continued to be used for sealing the lamp leads in the glass stem of the lamp until 1911, when it was superseded by a composite wire whose coefficient of expansion or contraction was about the same as that of glass.



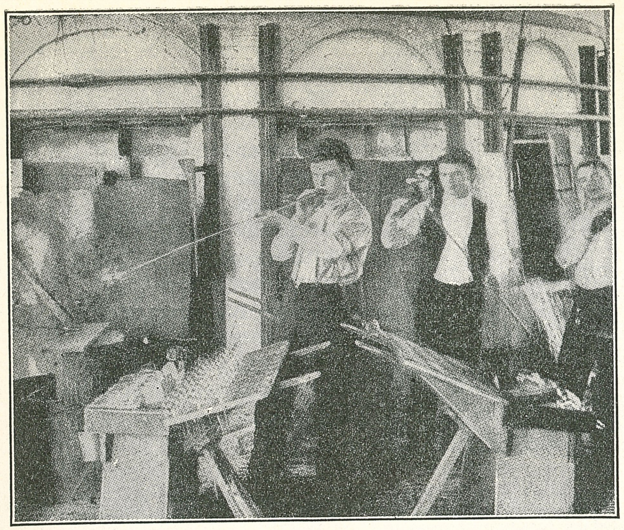
One of two busts made by James E. Kelly, artist, whose drawings illustrated an article on Edison in Scribner's Monthly in Nov., 1878.

warm water and thoroughly dried. The stems were taken to the glass-blowing department, and sealed into bulbs. From there they passed on to the pump room, where the occluded gases were expelled.

Here again I desire to call attention to the fact that the high resistance carbon filament lamp was exclusively the achievement of Edison and came into being on October 21, 1879. It was patented and its process of manufacture was described in the leading journals of the world. As a new invention, improvements naturally followed, and Edison sought this object after he had patented his great invention.

Bamboo was better than the carbonized paper filament, yet the paper filament was practical and its tests demonstrated its commercial possibilities. Now, if another person made a filament, he could not legally claim a complete lamp, for the filament was but a part of the whole. The process of making the filament, no matter from what material, and its treatment when on the air pump of driving out its occluded gases, was discovered by Edison. He was the first to employ, patent and document it. No one ever had accomplished that before, nor could anyone show plausible proof of having done it. Some did come to the fore, relating fables that were enough to incite the doubts of even the most unsophisticated.

The consensus of the world has long since given Edison moral and legal credit for his great accomplishment in making the first practical incandescent lamp.



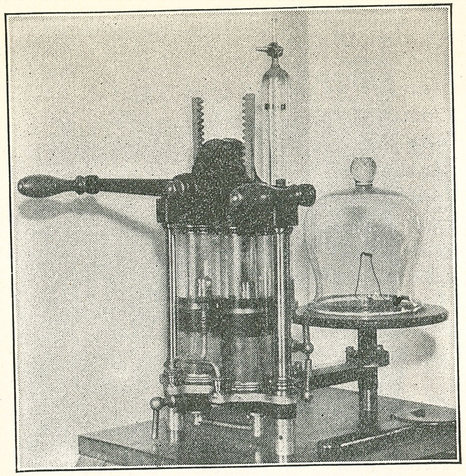
Making lamp bulbs in pioneer factory from molten glass taken from furnace.

LXXXII. The Lamp From Laboratory to Factory (PART TWO)

As I have mentioned, the pear-shaped bulbs were at first blown from glass tubing. When Holzer came, Edison had him experiment with bulbs blown from an iron mould. About the time the Edison Lamp Works were ready to start, the bulbs were ordered from the Corning Glass Works in New York, although I remember Edison had sample bulbs made elsewhere. The Corning bulbs were handmade, and blown from molten glass taken from the furnace.

The type of vacuum pumps used at the Edison Lamp Works at first was a simplified variety of the Sprengel. They were worked out at the laboratory for commercial purposes and used for many years here and abroad in all Edison Lamp Works.

I will now review briefly our work in producing a commercial vacuum at the laboratory. Early in 1879, while Edison was still experimenting with high fusible metals,



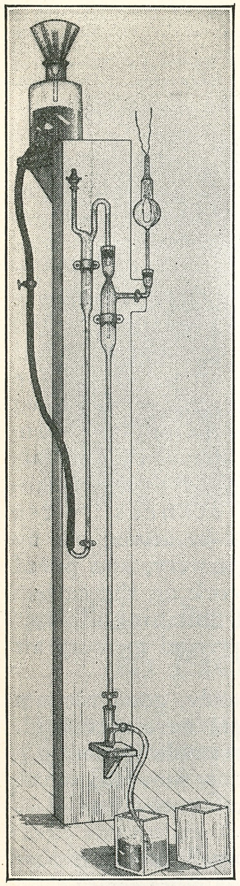
Mechanical air pump used by Edison during his discovery of occluded gases. Now in restored laboratory at Dearborn.

such as platinum, iridium and others known at the time, he began by placing them in a vacuum produced by a mechanical air pump. I have already described the result.(1) He found that metals and other substances were packed with occluded gases, which could be driven out by heating in a vacuum. It was a great discovery, and paved his way to success when he began his work on the carbon filament lamp. He then saw the need of obtaining a better vacuum and asked Upton to borrow a Sprengel mercury air pump from Princeton University.

Of the many attempts to produce a handy, good vacuum pump, only those of Geissler and Sprengel were successful. With either of these, scientists were at last able to obtain a high vacuum. Geissler invented his pump in 1858, while Sprengel followed in 1864. Both were made entirely of glass and employed mercury.

It was our opinion that with the Sprengel pump a higher degree of attenuation could be attained, and more easily than with other equipment. Its action is based upon the fall of mercury into a drop tube, there forming at first small cylinders of mercury that take with them small columns of air. As the mercury descends into the drop tube it finally falls into a glass jar, and the air is liberated. The contents of the glass jar are poured from time to time back into the mercury reservoir that feeds the pump from the top. As the pump operates, the mercury cylinders and air columns grow smaller and

(1) Volume 1, page 250.

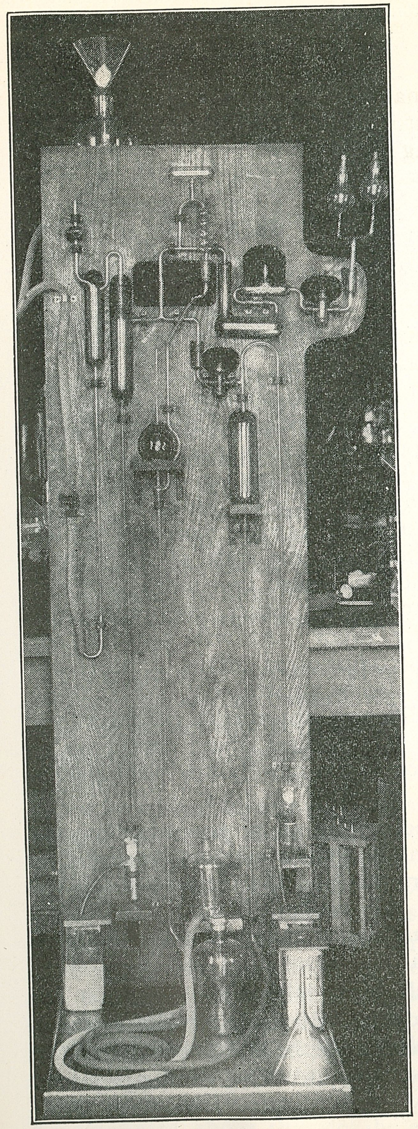


Early Sprengel air pump, as first used by Edison.

smaller, until the fall of the mercury into the drop tube makes a hammering metallic clink. The cylinder formation ceases. The mercury carries out particles of the highly attenuated air that look like specks, and these too finally disappear. At this stage, the vacuum was considered sufficient for our purpose. About five hours were required to exhaust the air and occluded gases from a lamp bulb.

The principle upon which the Geissler mercury air pump operated was more intermittent. The operator lifted a mercury-filled bottle, which was connected by a rubber tube to a glass tube that emptied into a glass chamber. When the bottle was lifted, the mercury flowed into the glass chamber, filling it. A stopcock was turned and the bottle was placed on the floor, so that the mercury could flow back into it. Thus a Torricellian vacuum was created in the glass chamber, and when another stopcock was turned to open the passage leading to the lamp bulb, the air in the latter rushed into the glass chamber, or became attenuated. This operation continued until the air became so rarefied that the vacuum was considered sufficient.

Of course, both these pumps were so constructed and operated that account could be taken of the barometric influence. The Sprengel pump, with some modifications made by Edison, was used in all our lamp experiments. When Edison wanted to give a demonstration of his system in 1879, he needed a large quantity of lamps, and to obtain them used a combination of the Sprengel and Geissler air pumps, that is, he had a Sprengel pump connected to a Geissler. His

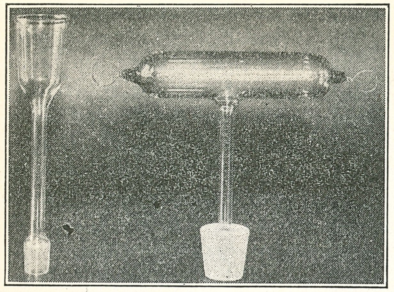


object was to pump out most of the air by means of the Geissler, and then finish the job by letting the Sprengel pump perform the higher exhaustion. We made three such combination sets. Because of the Geissler, an attendant was required for each set.

With these three sets and three men operating them, we commenced the production of incandescent electric lamps in quantities. We could make about twenty to twenty-four lamps in twenty-four hours, and that was considered good for a product of which the world still had but a hazy idea. The lamps were of the paper horseshoe type of filaments. With these combination air pumps we later exhausted many experimental bamboo filament lamps, although special experiments were always made with the Sprengel.

Here I might mention that when we first

Combination Sprengel-Geissler air pump used in making the first large quantity of lamps for the 1879 demonstration. Now in restored laboratory at Dearborn.



Left—Conical-shaped glass receptacle in which rubber cork fitted. Right—Spark gap in which approximate vacuum was estimated.

commenced working with the Sprengel, in 1879, Edison had our glass blower insert a small chamber just under the place where the tubulating tube of the lamp was connected to the pump. In it Edison placed phosphoric anhydride, to absorb the moisture contained in the air.

As in the experimental days, Edison always heated the bulb with an alcohol lamp, and this rule was always followed when lamps were on the pump for exhaustion. I must also note that when Edison made the combination of the Geissler and Sprengel pumps, he added a McLeod gauge to measure the state of the vacuum, a spark gap by means of which, with the aid of an induction coil, the state of the vacuum could be estimated. To these he added two more chambers, one to absorb the moisture and the other, containing gold leaf, to absorb the mercury vapor. As will be seen, this combination was a rather complicated affair, difficult and expensive to make. It will also be noticed that this combination air pump, with its different absorption chambers and connecting tubes, inclosed a great deal of air space, which always had to be exhausted when new lamps were put on the pump.

Connections and stopcocks were all of ground glass, and some had mercury seals which, with a mercury reservoir for the Sprengel and two others working the Geissler pump and McLeod gauge, completed the outfit. What I have so far described gives the reader an idea of the methods used in the laboratory in exhausting air and gases from the lamp bulbs.

When Edison had finished his laboratory work on the bamboo filament lamp, and believed the time had come to produce lamps on a commercial scale, he had to commercialize his lamp-making laboratory methods. One of the problems at this stage was the simplification of the vacuum pump system. Edison was convinced that the pumps so far used

were too elaborate and complicated to be adapted successfully in the new work.

Edison entrusted me, as well as W. S. Howell and W. J. Hammer, with this task, telling us to do away if possible with the ground glass stopcocks, joint connections, mercury seals and glass tubes in general.

'Start,' he said, 'with the Sprengel or continuous drop principle, for it presents the most favorable chances for improvement.'

In those days it was thought that a perfect air-tight joint or stopcock could only be attained by having its parts well-ground and greased; and to make them still more certain, they were inclosed sometimes in mercury seals. Edison said he thought too much fuss was made about this, and he was sure things could be pared down considerably. I felt highly honored in being entrusted by him with this work, and immediately set about the task of trying to eliminate first the ground glass stopcocks, joints and mercury seals. Edison told Glass Blower Boehm to make anything we requested, but when the latter learned what we were trying to do, he shook his head sadly and said that it would be impossible to simplify the Sprengel in any way, that we could not do away with ground glass cocks or joints in vacuum work.

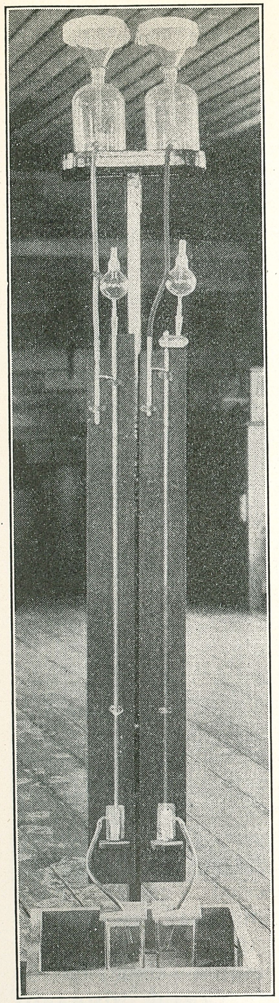
I had acquired a good deal of knowledge about air pumps during 1879, and as I was always at Edison's side from the start when he was personally conducting some air pump experiment, I had gained valuable experience in this line of work.

As I also had charge of the testing and photometer room, I began my work there and kept it under lock and key so that the other boys would not 'get wise' to what I was doing. Edison would come in occasionally to see how far I had gone and to offer suggestions. After working on various ideas it happened one day that I was talking to Dr. Haid in his chemical den next door to the photometer room, and noticed on his side table various Eimer and Amend's conical rubber corks with a hole through the center. I was well aware of these rubber corks, for we too used them upstairs in research work, but now the idea struck me to try them in connection with the vacuum pump work. When Edison heard about the idea he encouraged me to go ahead and try it. I went over to the little glass house and had

Boehm blow a cone-shaped glass receptacle, into which the rubber cork fitted. This was then fused to the stem whose other end terminated in the ground glass stopper inserted into the air pump. It was our custom in those days to seal the tubulating tube of the lamp onto a glass stem whose other end had a ground glass stopper that was inserted in the air pump and so made connection with it. Inserting the tubulating tube of a lamp, whose bulb was to be exhausted from air and occluded gases, into the central hole of the rubber cork, I placed the whole onto the Sprengel pump and set it into operation. I poured some mercury over the rubber cork to act as a seal. The progress of the Sprengel air pump soon indicated that it was working satisfactorily, and in a few hours the vacuum had arrived at which we were ready to drive out the occluded gases from the filament. When the gases had been driven out the lamp was sealed off and the experiment clearly demonstrated the ground glass connections were not necessary in a commercial vacuum pump. I also found the mercury seal was not necessary, for if the rubber cork had leaked the pressure of the atmosphere would have driven it through into the pump. However, on the other hand it served as a telltale, indicating either a good or bad connection. Edison came in often and watched the experiment and was pleased, while Boehm would not believe it.

Then I tried another experiment by inserting, instead of a lamp, a spark gap so that the state of the vacuum could be estimated approximately, and that experiment, too, made it clear that the rubber cork held the vacuum just as well as the ground glass connection one. Then smaller and smaller rubber corks were tried and the end results were that rubber tubing was equally as efficient as the corks. A piece of thin, pure rubber tubing about one-half inch in length was slipped over the end of the lamp's tubulating tube and then placed on the pump. It was found that it was well to grease the rubber tubing connection a little as it facilitated the operation of putting it on the tube and taking it off.

The next work was to cut down the glass tubing, etc. of the Sprengel air pump to such a degree that would not impair its practical usefulness. These experiments in eliminating all the unnecessary glass tubing and other parts of the Sprengel air pump were so successfully reduced that a simple, efficient and practical mercury Sprengel form of pump was made for commercial purposes. The pump took up less



Air pump as simplified for practical purposes. That on right has drying chamber. Note conical glass aperture.

space; it did not require an expert glass blower to make it; and it was inexpensive. The cubical volume of space in the inside of the glass tubes was reduced to a minimum. From the illustrations shown of the Sprengel-Geissler combination, the Sprengel alone and the end results of the eliminating experiments, these three cases are well presented in a pictorial manner that speaks more than words. Each of these three pumps could create a high vacuum, all that was necessary for the production of lamps; yet the simplified one was the easiest, safest and most practical one to manipulate. Boehm was disconsolate, for he said that the art of glass blowing in general had slipped into a factory process.

We tried these simplified pumps for a few weeks. Edison, finding them all right, ordered Holzer to make a few hundred for the lamp works. Holzer was assisted in this work by Hipple whom Holzer had taught glass blowing at the little glass house. For the drying chamber of the pump we tried sulphuric acid, sodic hydrate and the phosphoric anhydride that I have already mentioned as the moisture absorbant that we had used in all former pumps. This latter chemical was then definitely selected by Edison for the pumps in the lamp works. The Edison Lamp Works here and abroad used this type of vacuum pumps for many years. Small changes were made later on, but fundamentally they remained the same; the chamber containing

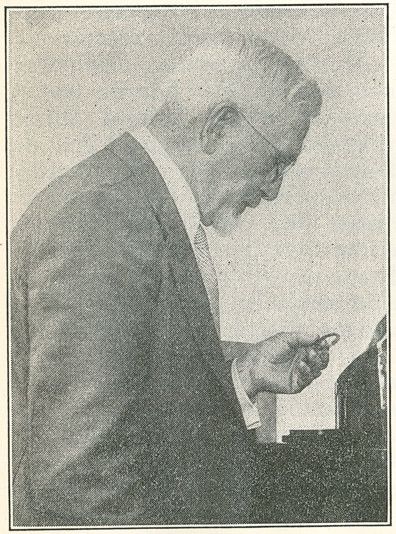
the phosphoric anhydride was later made separately and connected to the pump by a separate connection so that the chemical could be easily removed or renewed.

William J. Hammer(2) as well as Wilson S. Howell well remembered the time when the lamp pump competition was on, and only a few years ago, Hammer recalled it in a letter to me, saying among other things the following:

> 'You won the prize—we turned out 50,000 lamps the first year and for years your pump was used entirely for exhausting the Edison lamps.'

Wilson S. Howell, who is still among the mortals and lives in California, mentioned, in a letter to me, the same in other words. He said:

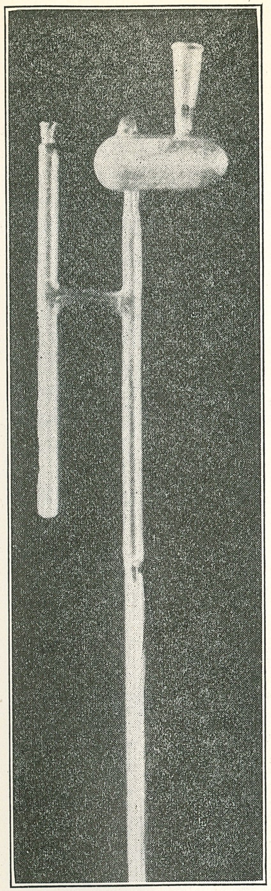
> 'I remember that we boys were all jealous of you for having designed the pump which was accepted for the new lamp factory.'



Wilson S. Howell in 1935, during visit at Ford Building, San Diego Exposition.

The vacuum pump department of the first lamp works at Menlo Park was installed under the supervision of Francis R. Upton, who was assisted by William J. Hammer. It was Hammer who mounted the first 200 simplified pumps at the lamp works, together with the resistance boxes used in driving out the occluded gases. Each pump had its own resistance box. I may mention that Edison preserved one of these pumps and years later donated it to the historical collection that was in possession

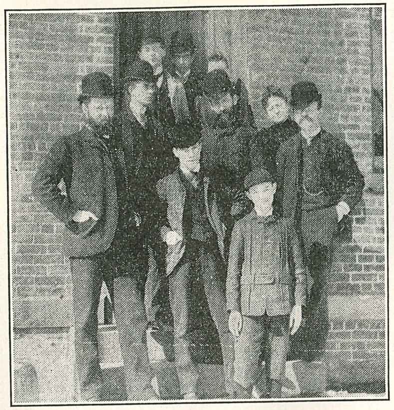
(2) William J. Hammer has since passed away.



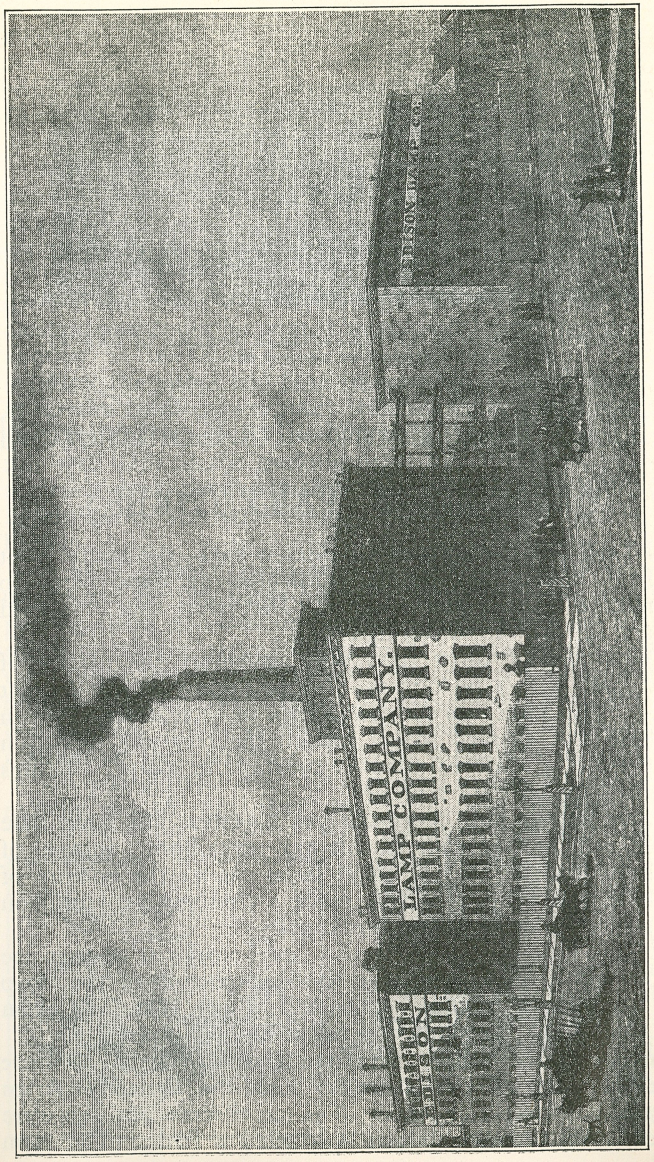
Close-up of simplified pump. Now in restored Menlo Park laboratory at Dearborn.

of the Association of Edison Illuminating Companies and Edison Pioneers. When Henry Ford arranged to restore the Menlo Park Laboratory at Dearborn, Michigan, this special pump and many other relics were donated to him by the Association of Edison Illuminating Companies, and today they can be seen at the Edison laboratory. The vacuum pumps in the first lamp factory at Menlo Park were mounted in aisles and one attendant could take care of many, for it was not necessary to replace the mercury in the reservoir as it flowed into a jar, as we used to do in the laboratory. Edison obviated this procedure by connecting each pump to an iron pipe line by means of a piece of rubber tubing, while likewise the mercury that flowed out of the pumps passed into another iron pipe and was collected into an iron reservoir from which it was raised to the upper feeding reservoir by an Archimedes screw pump. The piece of rubber tubing that connected the vacuum pump to the upper iron feeding pipe had an iron clamp with a screw by means of which the flow of mercury into the vacuum pump could be regulated. I may also mention that the short glass tube of the vacuum pump to which the rubber tubing was attached had a contraction to prevent too much mercury from flowing into the vacuum pump, but it was soon found that the iron clamp could do all the regulating. Other little tricks were tried such as placing a tiny small glass funnel into the bore of the

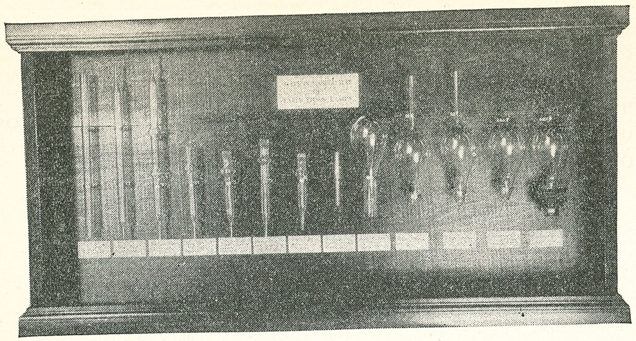
glass tube at the top where it was connected to the rubber tubing, but that did not prove of much value in regulating the flow of mercury. Of course, great care had to be taken in keeping the mercury clean and it was also necessary to clean the vacuum pumps from time to time. As time went on and more practical experience was acquired, small changes or additions were made that facilitated the operations and made the production less expensive and the lamps more efficient. At first when the Edison Lamp Works were started at Menlo Park it was the custom to heat the lamps from time to time with an alcohol lamp, and likewise the lamps, when exhaustion was finished, were sealed off by means of an alcohol lamp and blow pipe. More practical improvements followed these methods of operation and it was not until about 1896 that the General Electric Company introduced a new system of exhaustion—a mechanical-chemical one—that produced radical changes in the art of creating a vacuum in lamps. (The General Electric Company, formed in 1892, then became the guardian of all the Edison industries.)



Group before the Edison Lamp Company's office at Harrison, New Jersey, in 1889. Front row (left to right): Francis R. Upton; George J. Delaney (office boy); William Kirker, messenger boy; William H. Meadowcroft, assistant to Upton. Middle row—Charles H. Heeley, accountant; William Bailey, clerk; Mrs. Holmes, stenographer. Back row—Herman Borneman, clerk; Nelson Durrand, clerk; Jennie McNally, bill clerk. (Photo taken by Wilson S. Howell.)



The Edison Lamp Company's factory at Newark, New Jersey.



Steps in manufacture of early Edison lamps. Arranged by John W. Howell and displayed in restored Menlo Park.

LXXXIII. The Lamp—Its Commercial Manufacture (PART THREE)

IN THE first lamp factory at Menlo Park, the lamps went from the pumps to the glass-blowing department to receive the finishing touches. They were then inspected and sent to the socketing room.

Old-timers of those days will remember the plaster of Paris base, with a bevel brass ring and screw as the contact pieces. This form was soon found not to be practical. When the base was screwed into a socket, the resulting strain on the plaster of Paris resulted in constant breakage. Things were in a quandry for a while.

After Edison and Bergmann got together, the lamp base —such as it still persists to this day—was born. Instead of the bevel contact ring, a small brass cap at the bottom of the base was adopted. This made a compression strain on the plaster, obviating the breakage.

Edison sent Bergmann to the lamp works at once to see Upton and have him change the construction of the lamp base accordingly. This happened in June, 1881, and from that day to this the same base has remained in principle.

In basing the lamps, metal moulds made in halves were placed together in bevel apertures bored out in narrow strips of wood that formed a stand. The metal screw and cap were placed in the mould, which was oiled a little. The stem

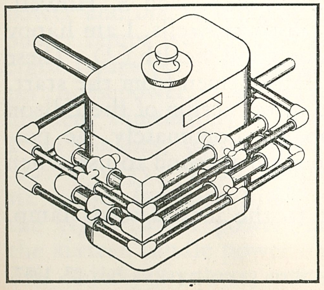
of the lamp was then inserted, with care that the copper lead wires were properly led, one to the screw and the other to the cap contact pieces. The lamp bulb was held by iron prongs attached to a rod that could be slid up and down. Thus the lamp could be properly regulated into position, into the moulds.

Next a composition of plaster of Paris was poured into the moulds and allowed to set. The screw ring and cap contact pieces were held together onto the lamp stem. The copper lead wires were then soldered onto their respective contact pieces. The work in basing the lamps was done in rows. The lamps were so arranged that the plaster of Paris composition could be poured successively from one mould to another.

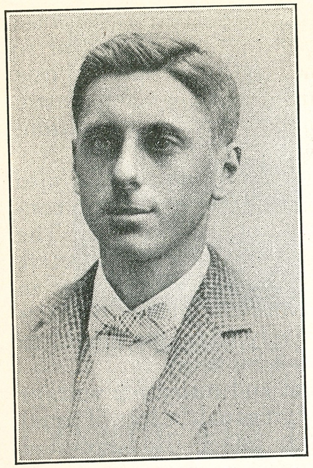
After the lamps had been inspected and tested for voltage at sixteen candle power, they were segregated in lots of equal voltages and labeled. The lamps that passed the inspection test were sent to the packing department to be shipped. In the early days, the lamps that were sent out from the Edison Lamp Works were well-wrapped in paper and packed in light barrels.

I have already mentioned in former articles how we carbonized the raw paper horseshoe form of filaments in 1879, putting them into iron or fire-clay boxes, separating them by tissue or tracing paper, filling the box with carbon dust and then subjecting it to a gradually increasing heat in a muffle furnace. When Edison began his experiments with the bamboo filament he had to modify the process of carbonizing on account of their shanks. This has already been explained.

At first Edison tried to carbonize a few filaments in a narrow mould, but they contracted into different shapes unsuitable for his purpose. Then he began to carbonize them separately in small individual moulds. It was in June, 1880, when he made some experiments with a specially designed oven made of fire-clay, in which he used gas and compressed air to



Experimental gas furnace tried by Edison in 1880.



John W. Howell, in 1881, when he first entered Edison's employ at lamp works, Menlo Park.

supply the heat. The gas and air were conducted into the four sides of the oven, and the graphite container, into which the filaments, each in a separate mould, were packed, was placed inside. To prevent the oxygen that liberated during carbonization from acting on the filaments, a separate tube was led into the oven and placed in connection with the graphite filament box. Before starting the fire and also while it was burning, hydrogen gas or hydrocarbon was introduced to take up the oxygen and prevent it from damaging the hot filaments.

United States Patent No. 248,423 was granted to Edison for this furnace and we tried it out at the laboratory. His idea in general on this matter was right, for it is very important in effecting good carbonization to find means to exclude or hinder oxygen from coming in contact with hot filaments during the process. Edison knew that such a reducing gas should also be present when the filaments cooled down.

In July, 1881, a young man named John W. Howell was put to work by Edison in the lamp works. He had just graduated from the Stevens Institute of Technology in Hoboken, New Jersey, and had written a fine thesis on the Edison System.

John W. Howell was the brother of Wilson S. Howell, whom I have already mentioned. Both Howells, I am happy to say, are still alive and enjoying good health.(1) These brothers have always been stanch Edison men from the start. Wilson devoted his abilities to the introduction of the Edison system, and in helping to develop it. Fortunately, he possessed the faculty to determine the right method to use when electrical pioneering was young.

John likewise devoted his life to the incandescent lamp,

(1) John W. Howell, since this article was written, passed away on July 28, 1937.

and became one of the leading lamp experts of the world, not only technically, but also as a legal authority and economic lamp engineer. His exploring abilities led him to effect many improvements in commercial lamp production, and his inventive talents helped to produce automatic labor-saving machines. His one objective was to better the lamp commercially, and through all its transitions in the Edison Lamp Works, the Edison General Electric Company and finally the General Electric Company, he remained steadfast at his post as an expert lamp engineer. When he first came to the Edison Lamp Works at Menlo Park in 1881 (as he wrote me) the bamboo filaments were placed in carbon boxes, but he adds:

'We soon learned to pack them in peat moss which was first roasted. This shrunk the same amount as the bamboo and kept the fibers in shape. When we left off the shanks, everything was simpler and we packed large numbers in peat and carbonized them. We carbonized them in two operations, the first was done in iron boxes—up to 600° Fahrenheit. These were heated very slowly, for if we went too fast the tar which was distilled out of the bamboo and peat would come too fast and stick all the carbons together. The first heat took from six to eight hours. The second carbonizing was done in graphite boxes and they were run up as fast as possible to a white heat. The first was called the preliminary and the second the final heat. All the shrinkage took place in the first heat, the mass of peat and fibers shrunk away from the box leaving an empty space all around. This mass of peat and fibers was put bodily in the graphite crucible or box. Many thousands could be put in one box.'

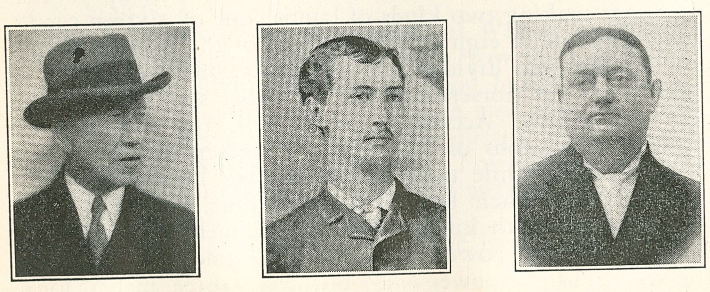
When John W. Howell joined the Edison Lamp Works, they were making two kinds of lamps, one of sixteen candle power and one of eight. Manufacture of the sixteen candle power lamps was divided into two sorts, one being rated at eight lamps per horsepower and the other sort at ten lamps per horsepower. According to Howell, the raw bamboo filament dimensions of the eight per horsepower were .008 x .017 inches, while those of the ten per horsepower were .008 x .0135. Their length, not including the shank, was six inches for both kinds. The raw filament dimensions of the eight candle power lamp had the same cross section as the sixteen candle power ones, but were three inches long. The object, of course, was in one case to produce lamps that

possessed a long life, while in the second they had a better efficiency but less life.

I have already mentioned elsewhere the splendid work William Holzer did in organizing the glass-blowing department of the Edison Lamp Works and placing it on a commercial basis. The art of blowing glass objects from glass tubes, using a table or bench supplied with gas and air bellows, was considered at that early date an exotic profession. Few such artisans could be found in America, and now the call came to transform that art into a factory process for mass production. Holzer had the ability to do that kind of work, for he was not only an efficient glass blower, but also practical. He gathered about him farmer boys and others from the neighboring villages, and gradually made out of them good glass blowers. Some even rose to become masters of the art.

Conspicuous among them was Joseph F. McCoy. He excelled in glass blowing, and was later selected by Edison for personal experiments when the lamp factory was in Harrison. Edison perceived that McCoy possessed other abilities that would be more useful in another field. Later McCoy became a confidential agent for Edison in many ways. If Edison desired anything, McCoy could procure it. If he wanted to know this or that, 'just between us,' McCoy was the man; his outside work was always credited with efficiency. Lately he has retired, and his robust health shows no affects of his long service to Edison.

Benjamin Moffett also rose and became a master glass blower and set up his own shop. So did Matthew Hankins and others.



Three pioneer lamp makers. Left to right—Joseph F. McCoy (known as 'gum shoe' McCoy), Benjamin F. Moffett and Matthew Hankins.

Glass blowing crew. In center, rear—Wm. Holzer; left to right (standing)—Will Emmons, ————, Charles Wood, C. Belose, E. Cutter, I. Fleming, J. Powers, George Lake, C. Benny, J. Fagan, Ben Moffett, Joe Force, Fred Hamm, Wm. Bogan, Frank Holzer, Jim Hipple, Charles Stillwell; middle row —W. Hart, P. Stauffer, Wm. Petry, ————, N. Thorp; sitting—Wm. Thorp, Joseph McCoy, Matt Cooper, W. Blackford, F. Mockridge, Matt Hankins, Wm. Ruhle, Wm. Marshall, A. Paine, ————.

Francis R. Upton, Batchelor's successor as general manager of the Edison Lamp Works, gave a terse description of the Menlo Park Lamp Works in 1883, as follows:

'In April, 1880, the manufacture of the lamps was commenced at the laboratory in Menlo Park with a payroll and organization separate from the experimental work then being carried on there. Previous to this time no distinction had been drawn between manufacturing and experimental work in the division of labor, though a large number of lamps had been made.

'In the summer of 1880, Mr. Edison bought the building at Menlo Park where at one time Mr. Batchelor and Mr. Kruesi had made the Edison electric pens. Early in the fall Mr. Batchelor gave his entire time to the manufacture of lamps, and under him a large amount of money was expended in making the various tools and in experimenting on the best method of manufacture. Mr. Batchelor deserves much credit, because under his management the most discouraging obstacles were encountered. Everything was new when the attempt was made to change from laboratory methods to manufacturing processes, and from use of skilled labor to the instruction and employment of unskilled men and boys.

'In January, 1881, I took charge of the factory; Mr. Batchelor's health having given out.

'Up to March, 1881, all the power used at the factory was carried on a wire from the laboratory—a distance of about a half mile—by means of electricity, using Mr. Edison's machines for generating and receiving the power. In March, 1881, an engine and boiler were procured for the lamp factory in order to free the engine on the hill from extra draughts on it and to make the establishment separate.

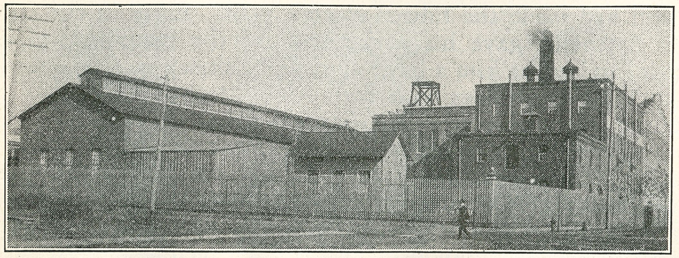
'Trouble was soon met with in Menlo Park of procuring suitable labor, especially light labor as boys and girls. Mr. Edison wishing to be secure, in the summer of 1881 purchased the present factory at Harrison, or East Newark, so as to provide against any emergency.

'This factory was partly burned before purchasing it, bringing it into the market at very advantageous terms.

'The Menlo Park lamp factory was thought to be a good place for trial of experiments before starting in the new place so as to save expense in fitting.

'On April 1, 1882, all manufacturing ceased at Menlo Park as it was decided that the process of making lamps was sufficiently settled to warrant the large investment required in fitting up the new place.

'The Harrison factory was formerly occupied by the Peters Manufacturing Company, makers of oilcloth. The buildings are in a yard which takes an entire block. There are three four-story buildings standing and the ruins of another, besides boiler room, office, stables, dwelling house, sheds, etc. The main buildings have about ten times the floor space of the Menlo Park factory, and without building



Buildings purchased by Edison in 1881 at Harrison, New Jersey, for use in lamp manufacture.

additional buildings more than ten times as many lamps can be made a day.'(2)

In the early winter of 1880-1881, Dr. E. L. Nichols was transferred from the laboratory to the lamp works to undertake the organization of the lamp testing department. He worked out a more practical method of measuring candle power of lamps in the photometer room than that used at the laboratory. He made two electro-dynamometers which could be used more handily in sorting lamps for voltage. They did the work fairly well, but of course were discarded as soon as ammeters and voltmeters of strong field type made an appearance.

'My successor,' Dr. Nichols wrote to me, 'was John W. Howell, to whom I turned over the plant when I resigned in the summer of 1881, to begin work as professor of chemistry and physics in a Kentucky college.'

Later, as we all know, Professor Nichols became a pillar of Cornell University.

Holzer became superintendent of the glass department, and James Bradley master mechanic. Philip Dyer was placed in charge of the office.

It is not necessary to emphasize the help that Batchelor, Upton and Kruesi gave Edison in installing and getting the Edison Lamp Works at Menlo Park in order. Their names shine brightly in the Edison story. Their position as the foremost of his co-workers is, beyond dispute, high above all others.

When the Menlo Park lamp works started to produce lamps for sale, it was late in the autumn of 1880. The first batch was used in the second demonstration during the winter of 1880-81.

I have already explained the policy of the parent company, The Edison Electric Light Company. It owned the Edison patent rights, but did not enter into the business of manufacturing. So they made an agreement with Edison, whereby he took over the manufacture of apparatus for his system. His contract as to incandescent lamps stipulated that he should sell them at a certain price.

(2) The Menlo Park Edison Lamp Works was started on October 1, 1880. The unskilled workers were first instructed, and the first regular payroll commenced on November 11, 1880. There were about 135 men employed. At Menlo Park about 80,000 lamps were shipped, while about 50,000 lamps were in the stockroom. The lamp works were moved to Harrison (then East Newark) April 1, 1882, and got started there on June 1, 1882, with about 150 men. The capacity at that time was about 1,200 lamps per day.

In starting this new industry, the cost of production was much greater than the stipulated selling price. Naturally, Edison lost money. However, he was confident that as factory facilities were improved and experience was obtained, the price of production per lamp would gradually decrease, until eventually he could make a profit. It was four years before he began to break even. Then a gain followed that soon redeemed the previous losses.

When I was in Europe for Edison, I remember selling thousands of American-made lamps at $1.00 per lamp. That price, of course, brought a profit, divided between the American and French companies. The latter owned the Edison rights for Europe.

Edison himself said that the cost of production during the first years was about $1.10 per lamp, while he had to sell them at $0.40 apiece. During the second year the cost went down to $0.70. The third year it sank to $0.50 and the fourth to $0.37. The profits in that year made up for all that he had lost in previous years.

Finally Edison got it down to $0.22 per lamp, and as they were made by millions and sold at the stipulated price of $0.40 a lamp, the Edison Lamp Company was making big money. It is on record that they paid a fat dividend every Saturday night. Frank L. Dyer wrote me that Edison frequently told him with great glee about declaring a dividend every Saturday night. It opened the eyes of Wall Street when they got wind of it and they coveted the concern. Edison sold out for $1,085,000.

In this series of articles on the lamp works, I have told how and with what facilities the first incandescent lamp factory began the production of lamps for commercial purposes. No new revolutionary changes came into effect during the succeeding ten years, yet during these years many decided improvements were made in the art of producing lamps.

EDISON in 1897.

LXXXIV.

'Subdivision of the Current' —The Three-Wire System

AFTER Edison had started on his great work, many journals and newspapers introduced the term 'subdivision of the light.' The phrase was a misnomer. Edison's object was to devise a system of general current-distribution and make a new kind of lamp, suitable and practicable for domestic lighting.

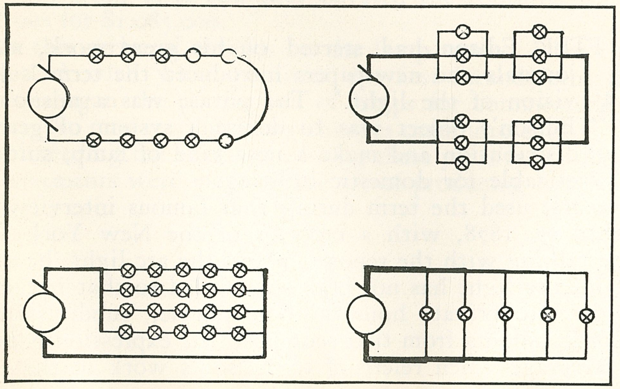
He first used the term during that famous interview([1]), October 10, 1878, with a reporter of the New York *Sun*. While talking with the reporter about the arc light, he said: 'The intense light has not been subdivided so that it can be brought into private houses.' The phrase, 'subdivision of the light,' sprang from that sentence; the expression became general usage when referring to Edison's work in the subdivision of current.

(1) See Volume I; Chapter XXX page 217.

The only system then in general use was the series-arc. The series system with variable tension was known as the *constant current* one. The variable tension was produced by inserting lamps or by switching them out through short-circuit. Where all lights functioned for a definite number of hours the series system was employed, as it is today for street-lighting or similar purposes.

Some of the numerous arrangements of the series system are shown in the drawings on this page. It was possible to make a type of series-parallel system as in Fig. 3. When considering these hookups, we see that should one lamp fail to function, the potential equilibrium of the system or of that special line becomes unbalanced. In this system (Fig. 1) when a lamp fails, all lights go out unless an automatic switch short-circuits the break or inserts a resistance; such a resistance, however, would be a waste of energy. When an automatic switch simply short-circuits the break, all lamps receive higher tension. Thus, the generator at the station must be of an automatic regulating type. The system shown in Fig. 3 requires a constant pressure. When a lamp goes out, it must be substituted for by an automatic resistance, until replaced by a good lamp.

The great advantage of the series system is that it can be extended to great distances by using high tension. The



Arrangements of series systems. Upper left—Fig. 1; Upper right—Fig. 2; Lower left—Fig. 3; Lower right—Fig. 4.

system can be used in special cases where the hours of lighting are fixed and where the public is unable to contact the line or its accessories, because of the high tension. In 1878 in this country an arc lamp was little more than an exhibition object. I remember paying a dime to see one in a circus that had thrown its tents opposite the Academy of Music on 14th Street, New York City. Edison had already thought out the fundamentals of the system he intended using—the multiple-arc or parallel system, shown in Fig. 4. This system is also known as the *constant potential* system.

As early as 1879, Edison decided that 110-120 volts should be the limit for general lamp voltage. These figures were based entirely on his judgment; he considered them safe limits for the public's use. This voltage has been the accepted one ever since. Perhaps you will smile when I tell you that in those early days only wet batteries were used; in the United States there existed but two or three small, crude, series-wound arc light generators and they were curiosities —110-120 volts was considered 'high tension.' Time has advanced that opinion; the most daring scientist of those days never imagined that a tension of 150,000 to 200,000 volts or more would ever become practicable.

Edison's problem was to make a lamp that would stand that amount of voltage (110-120 volts) and still be practical for his purpose. When he was 'on the right track,' the first experimental carbon lamps took only sixty volts. Through hard work and patience he gradually succeeded in raising the voltage to a value he desired. While others (Staite, Roberts, Farmer, Adams, Konn, Swan, Maxim and Sawyer) worked on low-resistance lamps with pencils or small rods of carbon as the light-giving elements, he directed his efforts to making a filamentary lamp of high resistance.

All who had taken up the subject before Edison had one desire—to produce something that would give light. They failed to recognize that electrically heating a substance to the point of incandescence is still not a lamp. A genuine electric lamp is a permanent contrivance for practical use. Edison went much further; he strived to produce a lamp of high resistance that could be used at a distance and that would still not require an excessive cross section of copper to conduct its current.

Others failed to produce any lamp of lasting qualities; their products seldom left the laboratory. Even had one of

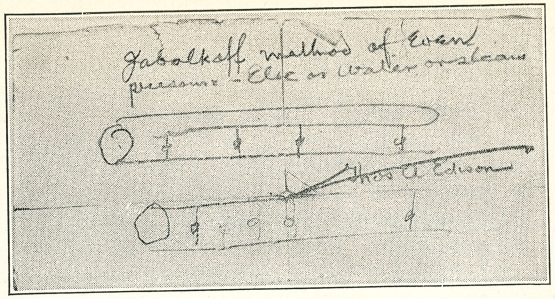
them succeeded in making a good lamp, its low resistance would have made it impractical for domestic purposes because of the excessive cross section of copper required for conducting the current to any reasonable distance. It never occurred to them to imagine the conductor question, as they had but the series one in mind. A system of central station distribution would have been considered a nightmare. Edison was a thinker and a famed electrician; he knew what was necessary.

As I have repeatedly emphasized, his high-resistance lamp embodied the laws of the transmission of electrical energy; his work on the lamp also brought forth the previously unknown fact that voltage multiplied by current is the expression for electrical energy. Had men understood Ohm's law at that time, they would not have taken recourse to the electrolytic cell in determining the value of a current.

Edison knew that with a known current and voltage, a certain effect could be obtained, and that the same effect might be procured by using less current and increasing the voltage accordingly—a fact that had been veiled in the realms of obscurity. That proves that Edison had at his command then the 'watts' which were christened as such by Siemens three years later. (1882)

Men had thought that only current (amperes) was power. Although Ohm's law existed, few imagined that there was any interdependence among ohms, webers (later called amperes) and volts. Edison's interest in this work took everyone by surprise. When they realized what he was doing, they saw that by a master stroke he had advanced the art of employing electricity for general purposes; they were not prepared for the work he had accomplished years ahead of their own efforts. Thus, this superior intellect was well prepared to take up a problem, seemingly grotesque to all. The foregoing explanation was necessary to obtain a better insight of the admirable manner in which Edison solved the difficulties of conducting current to a distance.

In many ways the multiple-arc or parallel system presented a flexibility essential to the distribution of current, for each consumer was independent of the other. One basic requirement of a distribution system is that the potential should remain practically constant, regardless of 'load' changes. Of course, the simple parallel system, shown on page 818, Fig. 4, could never be adopted for central station work



Sketch made by Edison. Courtesy of A. C. Steger.

because the pressure would vary somewhat when the lamps were 'thrown in or out' and the conductivity(2) value of the copper mains as a whole would be low. The amount of copper necessary in a simple parallel system would be so enormous as to make its use prohibitive for central stations. Edison was aware of this. His solution of the problem at Menlo Park was in itself another great invention necessary for the perfection of his commercial system.

He reasoned that the conductors of his system must be so arranged that, as a whole, they must possess the greatest conductivity value possible. He came upon the idea of dividing his conductors into three classes—one, the lighting or service mains; another, the feeders—both these classes of conductors served different purposes. The service or consumption mains were those to which the consumers were connected, while the feeder mains brought the current from the central station to various points of the service mains. To these service mains he added the third class, known as the coupling-conductors which interconnected the service mains at different points, thus making out of all an interwoven network of high conductivity to supply practically constant potential.

Edison's first patent on this subject was signed July 31, 1880, and was granted March 22, 1881, under No. 239,147. In the diagrammatic drawing Edison shows the basic fundamentals of his system; he had transformed the elementary,

(2) Conductivity is the reciprocal of electric resistance and is thus equal to $\frac{1}{R}$

simple parallel system into a system that obviates all the former drawbacks.

The invention of the feeder system was a marvelous feat and one which only the great electrical engineer of Menlo Park could have solved. Great scientists, including Lord Kelvin and others, had lost all hope of applying the pure multiple-arc system commercially. The feeder system retained the principle of parallel distribution and made current for light, heat and power applicable for all general purposes.

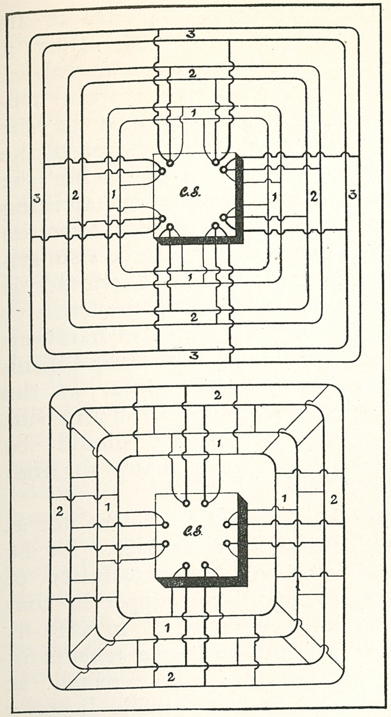
The service mains were connected to the consumers' premises and were kept at a constant pressure; should the pressure fluctuate, the candle power of the lamps would vary. At that time Edison thought the variance should not be more than two percent at full load. Since the feeder mains only supplied current at various points to the service mains, and as they were not connected to any lamps or their equivalent, we can calculate them with a permissible drop of pressure of ten or more percent at full load. Thus, by using feeders with a ten percent loss, we required only one-fifth the investment in copper, which was still much less expensive for the same load than a two percent loss in the mains.

Here we may notice Edison's strategic stroke of enhancing the value of the parallel system of distribution. Since the central station pressure was much higher, the feeder distributed current to the service mains at the required lamp-pressure, notwithstanding the large drop at full load. Thus, feeders bridge distance with economy; they carry all the current from the generating stations that is sent out.

Mathematicians found it an exciting game—calculating the 'Economy in Conductors.' Most of their propositions varied; the technical journals were full of matter on this subject. They drew up formulas for the best and most economical position for a central station. In practical cases, however, there are many other important factors to consider that change the theoretical aspect of the case. There are many interesting details connected with the technique of feeders, as well as the feeder system, which I shall not touch upon in this article.

Edison signed the specifications of his master-feeder patent August 4, 1880; it was granted September 19, 1882, under No. 264,642. In his patent he says:

'This invention relates to a method of equalizing the tension of "pressure" of the current of an entire system of



Drawing from Edison's Patent No. 239,147. The application was signed July 31, 1880. Patent granted March 22, 1881. Note consumers' mains, feeders and coupling conductors. C. S.—Central Station.

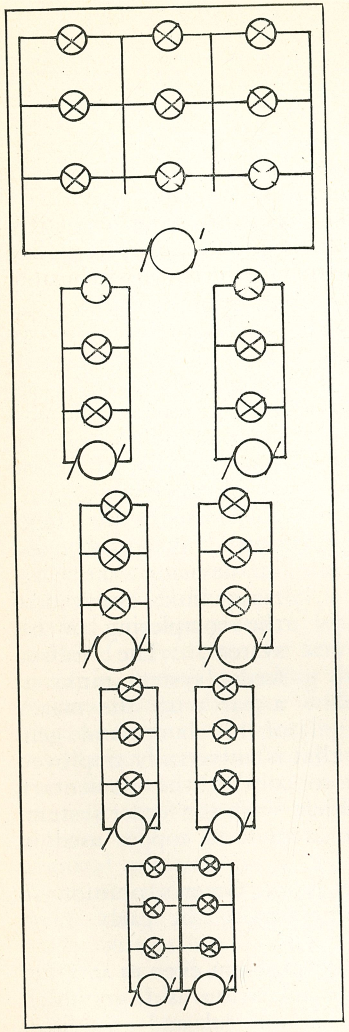
electric lighting or other translation of electric force, preventing what is ordinarily known as a "drop" in those portions of the system the more remote from the central station, and also to other features in systems for the utilization of electricity . . .'

Through his ingenuity, Edison succeeded in devising the 'last major link,' essential to the completing of his system. The Edison feeder system ranks at a par with the merits of his lamp and generator; all three form the system that is universally employed today. It was no simple task to convert the elementary parallel system into a network which, with the feeder system, economizes five or six times the amount of copper used in conductors.

The following extracts from Judge Green's opinion in the 'feeder' suit that was fought during the early days, emphasize this point:

'It goes without saying that no problem ever so severely vexed the marvelous ingenuity of invention as that which concerned itself with the safe, economical and successful distribution of electric light over a large area of territory by subdivision of the current.'

'It is difficult, impossible perhaps, to describe what invention is. If invention implies something more than a



Evolution of the three-wire system.

mere change of form or arrangement or mode of use, if it be the result of inventive, as distinguished from mechanical skill, if it be the result of the operation of the intellect, not following the beaten track, but striking out into some new direction and achieving some new triumph, if it be the resultant of the exercise of the creative skill and genius in harmonious combination, then I think Mr. Edison, so far as the matters involved in this suit are concerned, should be termed an inventor of high order.'

Still his mind was not at rest on this subject, for he surmised the possibility of reducing the copper in conductors further. In 1882-83 a plant having a tension of 330 volts was erected at Roselle, New Jersey. It was a small, experimental central station to be used in demonstrating the possibility of lighting small towns and villages where buildings were scattered. Edison wished to employ a distribution system requiring a minimum investment in copper conductors.

William S. Howell erected this unique plant. The 330-volt tension required three lamps in series, thus making the plant a multiple-series system one, operated by the Edison feeders. Since the

current price was reasonable and the wiring of their homes was free, the consumers consented to forego the individual control of the lamps. Although the plant was an experimental one, it remained in active operation for almost ten years.

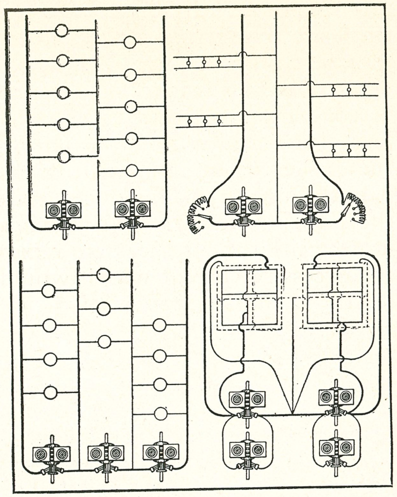
Edison was not satisfied; he wanted his system more flexible in every manner; he wanted each lamp independent of the other. Incidentally, the Roselle plant provided a diversion for Edison's mind. The resulting solution of this experimental plant changed a part of his former system, and brought a new event into the history of current distribution. In his mind he pictured two more conductors between the outer poles of the 330-volt one; he imagined what would happen if there were variations in the load.(3)

While visioning this 330-volt system with two extra wires between the outer ones, the picture in his mind gradually became blurred and faded away. Then slowly appeared four lines, each of the two inner lines forming, in a step-by-step fashion, a regular two-wire lamp system—each receiving its current from a separate generator. Gradually these two separate units approached each other until the two inner wires seemed as one of double section and the hookup appeared as a three-wire instead of two two-wire ones.

After this bit of speculative musing, Edison came down to the Goerck Street Works one day in the latter part of 1882. He instructed W. S. Andrews, who had succeeded me in the testing room, to get two 'Z' dynamos, running separately, and to branch each of their lines on a wide board; at that point each generator was to feed an equal number of lamps. Edison then connected the inner wires and began to remove lamps on both sides of the combined system; when all lamps on one side were taken out of action, the other side was not affected. In fact, he found that regardless of which side he switched on or off lamps, nothing of importance happened. *The three-wire system was born!*

Andrews told me also that the next day Edison made another experiment with a 'Z' dynamo, connecting its wires to the board where fifty-volt lamps (two in series) were substituted for the 110-volt ones. He then placed a middle

(3) We know that Edison was most proficient in making electrical hookups; should we analyze the intricate connections in his system of quadruplex telegraphy, we realize that those of his lighting system were much more simple. Edison once admitted that the technical wiring riddles of electric lighting never gave him the headaches he had while working on his quadruplex systems of telegraphy.



Drawing from Edison's application for patent covering the three-or-more-wire system. Signed November 20, 1882, and granted March 20, 1883.

wire between the lamps making it a three-wire system. He connected a dynamo brush, placed it a quarter of the distance away from the regular brushes, to the middle wire on the wooden board. This experiment gave results identical to the former test. By making the inner or compensating main of the same cross section as the outer one, the system would save 62½ percent in copper.(4)

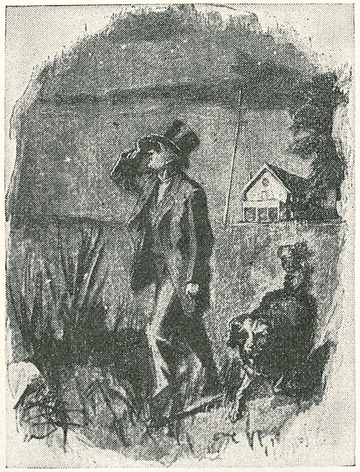
Hence with equal amounts of copper and the same percentage of loss in the mains, the three-wire system could be extended to 33⅓ percent greater distance than the two-wire system. It was not necessary to have the middle wire of the feeder mains of the same cross section as the two outer ones; thus there was also a saving when the middle wire was made smaller. The patent specification was signed by Edison on November 20, 1882; it was granted March 20, 1883, under United States patent No. 274,290. (The three-wire system is universally employed for central station current distribution today in cities.)

In his patent Edison clearly describes the object of his three-wire system as follows:

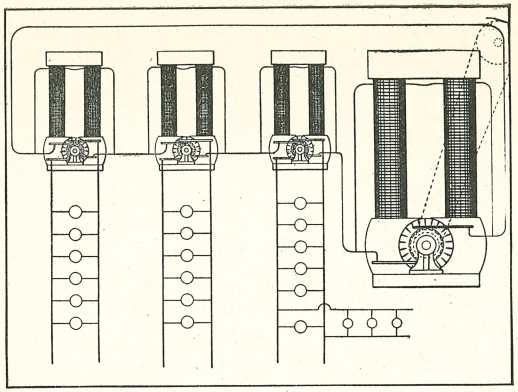
'To provide a system in which currents of high tension can be used, while at the same time each lamp is entirely independent of all the others, the lamps being also each of the standard or usual resistance, is the object of my invention, and I accomplish this by employing a source of energy of high electromotive force, arranging the translating devices in

(4) Coincidentally, the three-wire system was also invented by Dr. John Hopkinson of England, and by Dr. Werner Siemens of Germany.

multiple-series, dividing said source into as many parts as there are translating devices in series in any circuit, and correspondingly dividing each series of lamps, such divisions being made by means of a central compensating conductor or conductors between the divisions of the source of energy, and also between the translating devices, so that when all the devices in any multiple-arc circuit are in use, current will pass through all such devices, the current passing across from the positive to the negative main conductor; but if one or more translating devices are removed from any series-circuit, the excess of current which would otherwise affect the other lamps in the circuit is taken by the compensating central conductor, so that the other lamps remain unchanged.'



Artist's drawing of Edison walking home from laboratory at Menlo Park.



Drawing from Edison's patent covering transmission of power by the series system. Signed May 22, 1882, No. 265,786. Note motor generator or converter, reducing tension for consumption.

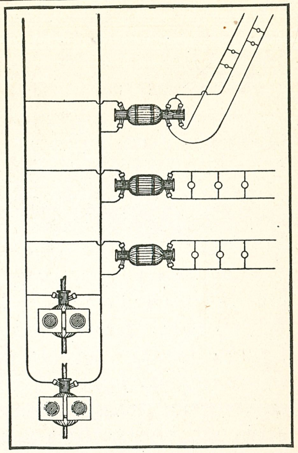
LXXXV. Transmission of Current

AFTER signing another specification on May 22, 1882, Edison was granted a patent October 10, 1882([1]), covering a system of electrical power transmission in which he described a series hookup that would deliver power on the parallel system to different stations. If I am not mistaken, the system was very similar to the one which my old friend Rene Thury of Geneva, Switzerland, worked out later by erecting several high-tension direct current plants.

Edison proposed the use of one or more high-tension generators at a central station where the generated current would be conveyed over a high-tension line, connected to motor generators or converters in series. Edison already had grasped the idea of utilizing a motor generator unit. His rotary converter consisted of two armature windings—each winding having its special commutator and brushes. The patent drawing gives a concise explanation of the entire system. The specification for such a motor generator was signed by Edison July 7, 1882; the patent, No. 278,418, was granted May 29, 1883.

(1) Patent No. 265,786.

Drawing from Edison's application for patent covering transmission of power by parallel system. Signed on May 8, 1883; granted October 30, 1883; No. 287,516. Note converters for the two-and-three-wire system.



The specification for Edison's high-tension, multiple-arc system, driven by motor generators, was signed May 8, 1883; the patent, No. 287,516, was granted October 30, 1883. Edison gave the following description of the system:

'The object of this invention is to provide a system of electrical distribution wherein current can be economically transmitted from a distant source of energy—such as water power—to the town, village or other locality which is to be supplied, and there distributed from different independent central stations, situated at convenient points to the various parts of such locality.

'Generally speaking, such a system consists of: (1) A sufficient number of electrical generators of high electromotive force situated at the source of power; (2) Main conductors of small area extending from such generators to the locality to be supplied; (3) Devices connected with such conductors in multiple-arc for reducing the tension of the current, each device or set of devices being placed at a distributing station; (4) A circuit or circuits extending from each of such distributing stations for conveying the low-tension currents, and translating devices—such as electric lamps or electromotors—connected with such low-tension circuits.

'The device which I prefer to use for accomplishing the reduction of tension consists of a field magnet and an armature core on which are wound two sets of coils, one of fine wire connected with a commutator whose brushes are placed in the multiple-arc circuit from the main conductors, and the other of coarser wire connected with a commutator from whose brushes the circuit or circuits extend, on which the translating devices are arranged, preferably, in multiple-arc.

The field magnets may be energized by a constant current in any suitable manner.

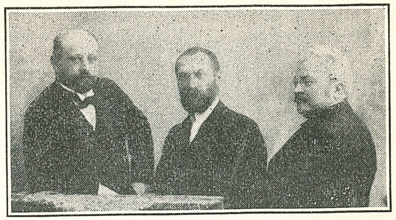
'Where it is desired to employ the compensating system set forth in my patent No. 274,290, I wind the core with three sets of coils, one acting as a motor coil, and the other two as generator coils.'

Thus we see that Edison already had given in 1883 the principles that control the laws of distance transmission, not forgetting that this notion already existed in his mind in 1878 when he visited the mining regions of the Sierra Nevada with Professor Barker.(2) He also showed how high-tension current could be converted to low tension through rotary converters for central station work. From the seventy-five patents that were granted to him on current distribution, transmission of electrical energy, wiring, etc., he opened the paths for transmission in general, no matter what the nature of the current was.

As is well known, the first systems of arc lighting were operated with the aid of crude alternators, and when Gramme in 1870 turned Pacinotti's invention to practical account, the direct current came slowly into use. At the Paris Exposition of 1878 arc lighting was mostly produced by alternating current, while at the Paris Exposition of 1881 arc lighting was overwhelmingly produced by direct current and soon the old generation of alternating current engineers slowly passed out of the picture.

A new generation soon appeared due to the Edison incandescent lamp and complete system of current distribution exhibited by Edison at the latter exhibition. The lamp proved to be the keystone of the birth of the future great electrical industry. The efficiency success of Edison's direct current generator further enhanced the expectations of both theorists and practical men, and a large number of both classes took to the electrical art that was just emerging into a general active state of usefulness. Work and experiments were mostly executed by the use of direct current, for this kind of current had advantages in many ways over that of the single phase alternating current. The greatest drawback of the latter was that no motor yet had been invented that could be used in a practical and general way like the direct current one.

(2) See Volume I, pp. 189.

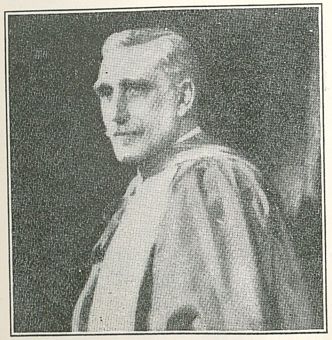


Left to right—Deri, Blathy and Zipernowsky.

Among the new class of engineers that appeared, a few, nevertheless, turned their attentions to alternating current. Most conspicuous among them were Zipernowsky, Deri and Blathy, engineers of Ganz and Company of Budapest, Hungary. Ganz and Company started their electrical department in 1878 with Karl Zipernowsky as engineer.(3) Later Max Deri and Otto Titus Blathy joined the company. In 1883 they erected at the Vienna Electrical Exhibition a 1,200 lamp alternator having a tension of fifty-four volts.

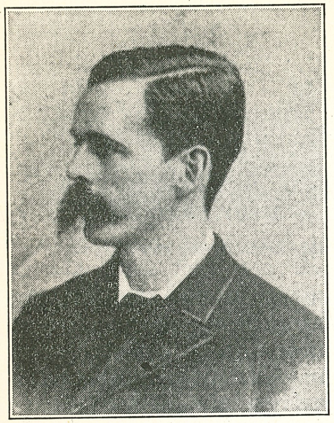
They were followed by S. Ziani Ferranti and J. E. H. Gordon of London, England, the former the engineer of Ferranti Company and the latter the engineer of Telegraph Construction and Maintenance Company.

Ferranti came under the patronage of Sir William Thomson (Lord Kelvin). In 1881 the firm of Ferranti-Thomson was formed. Ferranti once told a friend that his study of Edison's boyhood work made him determined to follow Edison. It was Ferranti who undertook a Herculean task when he erected the Deptford Station in England in 1888. He built a 100,000-lamp alternator and laid underground mains carrying 10,000 volts pressure. The electrical world admired his boldness, yet many were filled with apprehension. Some said that it would be either a grand success or a grand failure. Edison thought the idea was too big. He said that Ferranti had good ideas and that he was no small man.



Dr. S. Z. Ferranti, who built the Deptford alternating central station, employing tension of 10,000 volts—first of its kind.

(3) Ganz and Company is one of the great European companies that manufacture almost everything in the electrical and mechanical line and also build ships and railways.

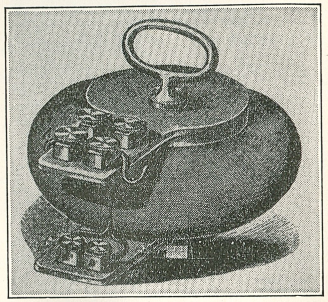


J. E. H. GORDON

J. E. H. Gordon, B. A., M. S. T. E., was a brilliant academic electrical engineer and constructor who built a 5,000-lamp alternator in 1882. He and Ferranti were England's most progressive alternating current apostles. Gordon was the favorite student of Clerk Maxwell, and was well known in scientific circles as author and lecturer. Gordon was a great admirer of Edison, calling him 'a genius and one of the greatest inventors of the age.'

In Germany there was the Helios Company. The Westinghouse Company of Pittsburgh, Pennsylvania, came into being in 1886. Thus the electrical fraternity was divided into two camps, and of course the dominant party was yet the direct current one.

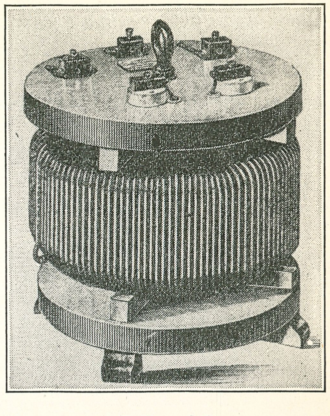
In May, 1885, a great surprise came to the electrical world, one that was to have a great bearing on the electrical industry of the future. I had some work to do for the French Edison Company of Paris in Bucharest, and while there my old friend, Etienne de Fodor, an Edison pioneer of 1881 in Europe, wrote me a letter requesting that I go to Budapest, visit the exposition, and make a study of the new system that Ganz and Company were demonstrating there in a practical way. I lost no time in extending a week-end vacation and went to the capital of Hungary. At the exhibition ground I found 1,000 or more incandescent lamps operating from an alternator running at a pressure of 1,300 volts.



Mantel type of Z, D and B transformer. In commercial use in 1885. Consisted of primary and secondary coils around which annealed iron wire was wound. Transformation rate was 1 to 10.

It was an 'eye-opener,' for the pressure was reduced to

that required by the lamps by means of many poleless induction coils for which the Hungarian inventors called or coined the word 'transformers.' These were scattered at various buildings and points of consumption about the exhibition, there being about seventy in all. The system of distribution was patterned after Edison's parallel one given in the United States patent No. 287,516.



Core type of Z, D and B transformer. Came after mantel type.

The inventors of this new transformer, Carl Zipernowsky, Max Deri and Otto Blathy, created a sensation. Electrical engineers everywhere recognized that electricity could now be transmitted from a very great distance. They were the first to demonstrate in a practical, commercial manner the success of their great invention. It constituted *an established historical fact.*

They exhibited it in London at the Invention Exhibition in the summer of 1885 and there Professor J. A. Fleming found that the transformer had an efficiency of 95 percent on full load. With the work that Zipernowsky, Deri and Blathy had achieved, alternating current technics were ushered into a new era of progressive activities that paved the way for long distance transmission. The principal obstacle was now conquered and what remained yet was to get a practical alternating motor and obtain experience.

As with Edison's lamp, many came running out of the woods to claim that nothing new had been done. However, if one looks up records he will find that with the work of Faraday, Jablochkoff, Bright, Varley, Fuller, Hartzma Enuma, de Meritens, Thomson-Houston and others, the problem might have been solved if any one of the old experimenters had known how to do it successfully. It is only the successful issue of results that counts in this world. As in a military action, he who wins the battle is the victor, although both sides employ powder and arms in the strife.

Elihu Thomson, that brilliant scientist, experimenter and

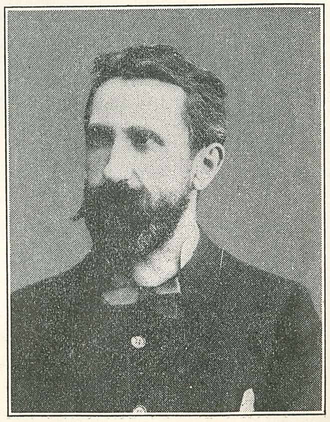
JOHN W. LIEB in 1883.

industrial engineer, had grasped not only these but other fundamentals that proved to be the last links wanted to complete the alternating current's victory. However, the professor during that time was very busy with his direct current work and business.

Continuing, let me note that Gaulard and Gibbs in 1882 patented an open magnetic core induction coil on the series system that never could be made generally adaptable for service. Dr. Blathy saw the system at the Turin Exhibition in 1884 and perceived where the hitch was. He returned to Budapest and in August, 1884, with his confreres, put the first successful and commercially practical transformer system on the electrical map.

The enthusiasm of many who tried to solve the induction coil transformation of current problem was caused by the fact that they could see their only salvation in the series system —*one thin wire*. Even Rankin Kennedy, mathematician, scientist and transformer worker, said: 'In the parallel arc, however, the secondary generator (transformer) is a beautiful self-governing system of distribution, but what about the size of the conductors for such a system? Prodigious!'

Interesting is the fact that the second order received in



PROFESSOR GUISEPPE COLOMBO

Founder of Italian Edison Company in Milan as he appeared in 1884. With John W. Lieb he visioned the importance of the transformer after its invention in Hungary.

1885 by Ganz and Company for their new system came from the ever-progressive Societa General Italiana di Elettricita, Sistema Edison, Milano, Italy, organized in 1882. Two men, Professor Guiseppe Colombo and John W. Lieb, had the vision and initiativeness to grasp the far-meaning importance of the Hungarian invention and ordered a plant for the lighting of the Theater dal Verm, situated about 5,000 feet from the Edison central station, and thus beyond the limits of the Edison mains.

The first transformers were shipped to the Italian Edison Company in Milan on December 17, 1885, together with two alternators and two steam engines, each of about 150 horsepower. Needless to say, the Zipernowsky, Deri and Blathy system proved a great success.

John W. Lieb, who was the chief electrician at the New York City Pearl Street Edison Central Station in 1882, had been intrusted by Edison to go to Milan, Italy, and there erect a sister central station along Pearl Street central station lines. It was not only the second in the world but also the first real progressive Edison one. Lieb studied the Budapest plant in 1885; was filled with enthusiasm and sent a full and detailed report to Edison and the Edison Electric Light Company, doing all that he could to impress them with the seriousness and importance of the newly invented transformer.

Answers came slowly. Lieb used all his influence. He even implored the Edison Electric Light Company to buy the patent rights for the United States. Unfortunately, they could not vision the commercial importance of the invention. In September, 1886, Dr. O. T. Blathy came to America and conferred with Edison and Edison officials.(4) As a result, Francis R. Upton, representing the Edison Electric Light Company, was sent to Paris, France, and there took up the discussions again with Professor C. Zipernowsky and Dr. O. T. Blathy, who left America in November.

It was at this time that I too had arrived in Paris from Vienna, and it happened that as I was sauntering down the Boulevard des Italiens one evening, I met Upton. Surprised to see him, I wondered what brought him to Paris. He told me about his mission and that he had come to an agreement in obtaining an option on the Ganz and Company's transformer for $20,000. Now it was up to the Edison Company

(4) The Zipernowsky, Deri and Blathy system was patented in all countries. In the United States their patent was filed on May 7, 1885.

to ratify it. I may mention that $5,000 was paid down and the rest was to follow as stipulated in the agreement.

No advantage was taken of the option and so the Edison Electric Light Company let the goose fly away that was to lay golden eggs in the future. It was another case like that of President Orton of the Western Union when he refused Bell's offer of $100,000 for his telephone patents.

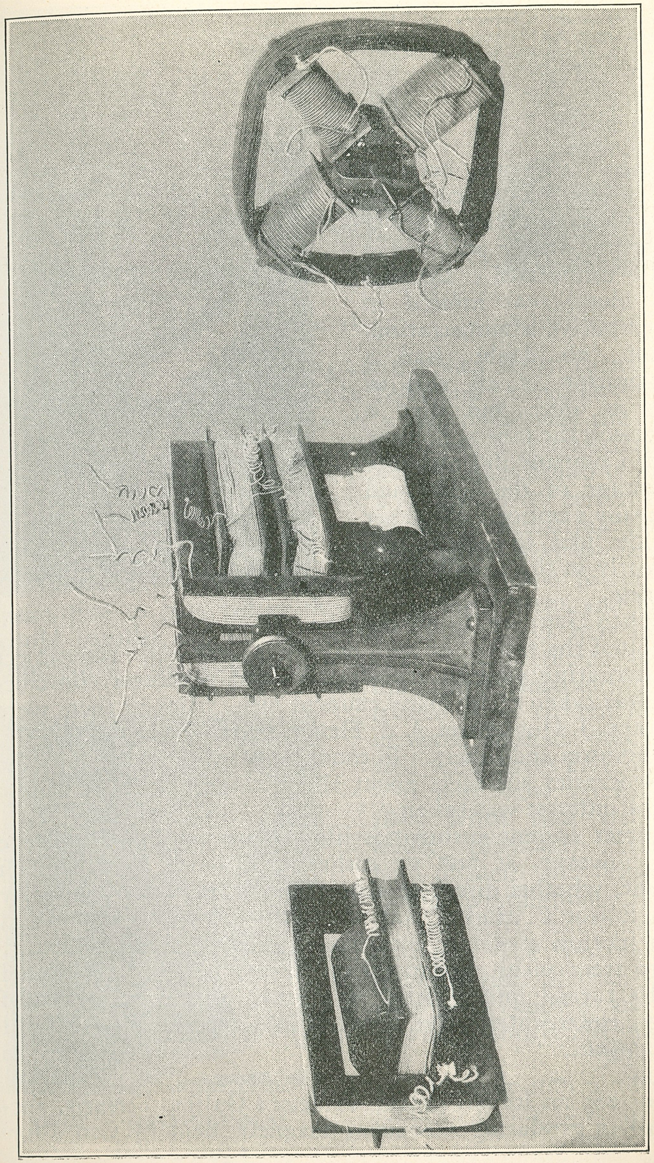
John W. Lieb regretted the fact all his life whenever he related the Ganz transformer offer to the Edison Company. He said that they put the agreement 'in the icebox and forgot about it.' They surely must have known what was going on in Europe, and the success that their sister Edison company in Milan, Italy, was having with their transformer plant. A little reflection would have convinced them that with the new invention alternating current was not to be despised, that sooner or later the alternating current motor would come. In 1890 Ganz and Company sued the Edison Electric Light Company to be released from the agreement made between the two parties in 1886 on the claim that the Edison company had not fulfilled obligations.

I often have wondered what would have happened if the Edison Electric Light Company had possessed a seasoned and experienced executive who could have organized a company on a permanent basis. We cannot blame Edison. He had created the industry, but he was wearied of the business part, and wanted to go back to free-lance work in his new laboratory in West Orange, New Jersey.

In the summer of 1886 the Edison Lamp Works, S. Bergmann & Company, the Edison Machine Works and the Edison Tube Works combined and were unified under the name of the Edison United Manufacturing Company, the general manager being J. Hutchinson. In December the parent company and the Edison company for isolated lighting were merged and called Edison Electric Light Company, the 'The' being left out.

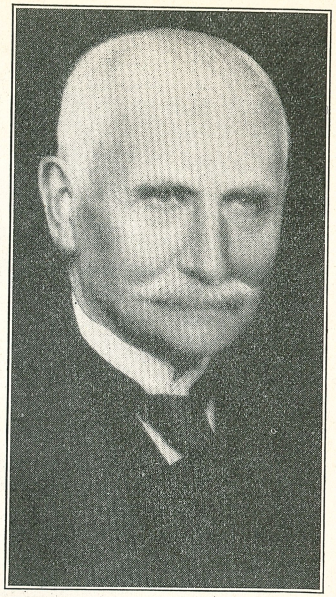
In 1889 all of the companies were combined and called the Edison General Electric Company. Then, for the last time, in 1892 this company was combined with the Thomson-Houston Company and called the General Electric Company. The new company was headed by a brilliant and able executive—Charles A. Coffin. It has kept green the memory of the great American who was the father of the industry.

With these continued series of mergers, consolidations



Models made by Professor Galileo Ferraris of his rotating magnetic field and given by him to John W. Lieb. Now in the Edison historical collection at Dearborn.

Charles A. Coffin, first president of General Electric Company in 1892, after merger of Edison, Thomson-Houston, Brush and Wood interests.

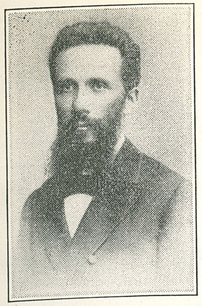


and combinations between the parent Edison company and its subsidiaries, it was clear that a new policy had to be formulated. In 1892 new blood was infused in the executive administration. Edison, no doubt, had a premonition of all this as early as 1885, and that is the reason the Edison Electric Light Company did not take advantage of the Ganz and Company's option. He never had the idea to remain permanently in the electric light business.

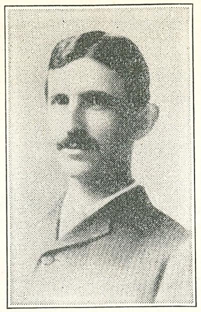
When Ganz and Company exhibited the success of their engineers—1885-86—the subject of alternating current, transformers and generator construction was taken up by many eminent men. Among them were G. Kapp, J. Hopkinson, J. A. Fleming, J. A. Ewing Blakesley, E. Thomson and others. In time they explained many of the idiosyncrasies and facts about alternating current, and more general interest was taken.

Direct current authorities like Edison and Siemens were not, however, at first so enthusiastic about high tension current, whether direct or alternating. From the very early days Edison's 'dander' was aroused when carelessly-erected high tension arc-lamp lines would 'sizzle' a lamp trimmer. There were many controversies on the subject. The final results turned into another angle and after some years of study, electrocution was adopted in some states as capital punishment, the first legal electrocution taking place in August, 1890.

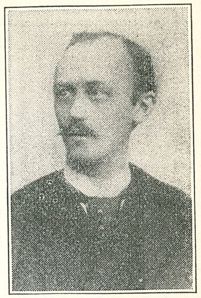
In 1885 an Italian savant, Professor Galileo Ferraris, succeeded in producing a rotating magnetic field by two alter-



G. FERRARIS



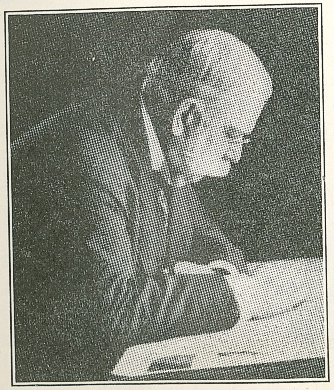
N. TESLA



DOLIVO-DOBROWOLSKY

nating currents. Alternating current men began to work in this direction and soon Nikola Tesla and Dolivo-Dobrowolsky appeared, the former with a two-phase and the latter with a three-phase system. These turns in progress created much work; there were many practical researches to be made.

As previously stated, it took a long while to perfect these systems before the menacing bugbear of alternating current established itself in a modest way and the business fears of direct current men were assuaged. They soon found that years had to pass before the alternating current and motor could parallel the Edison flexible system, and that in the meanwhile the alternating current would convey energy from the distance and convert it into direct current for use in those stations that operated with direct current.



GEORGE WESTINGHOUSE

I must now go back to 1886 when that dauntless leader, promoter, inventor, bold financier and organizer, George Westinghouse, started in the electric manufacturing business. The Westinghouse steam engines of that period were well known and employed by many electric arc-light companies. Why the Edison companies were never inclined to use it I don't re-

From *American Machinist*, May 22, 1886.

member, but I know that the Armington & Sims steam engine seemed to be the only one favored. Even in one edition of Bergmann's catalogue all sizes of the Armington & Sims engine were catalogued, thus displaying a sort of sisterhood.

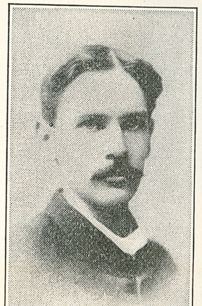
This and other things seemed to have riled Westinghouse who was a fighter. He was said to have uttered: 'All right, if I can't sell them any engines, I will make direct current machinery too and use my steam engines.'

Such were the rumors of those days. I know that there were taunters in those days. One would find in serious journals such jokers as appears in the ad above.

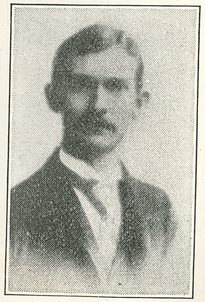
Not only did the indomitable Westinghouse soon build direct current installations; he also visioned the possibilities of the alternating current system. Seeing what had been done so far, he gathered about him a coterie of a few bright young men. There were William Stanley, Albert Schmidt, O. B. Schallenberger, L. B. Stillwell, Philip Lang, Charles F. Scott and others. In 1888 Nikola Tesla came and in 1889 that versatile genius B. G. Lamme, later chief engineer and a pillar of the Westinghouse company.

Thus, under the encouragement and guidance of the

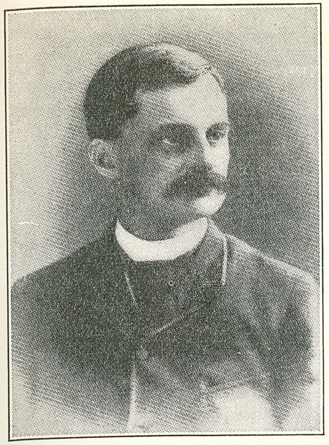
ALBERT SCHMIDT



WM. STANLEY



O. B. SCHALLENBERGER



ELIHU THOMSON, 1853-1937.

progressive Westinghouse, alternating current transmission research work was begun and what was accomplished is history. The Westinghouse engineers strained all efforts to bring out the virtues of the alternating current, and make it a success in America at any cost.

In another camp was the eminent Professor Elihu Thomson of the Thomson-Houston Company. He also delved into this alternating current problem. Thomson was one of the brightest of the academical scientists at that early period. He was one of the first pioneers in America to make theory and practice meet, and his series-arc-lamp system, together with his *three-phase winding* direct current high tension generator, was unique before any of the other alternating current men even began to have much of an idea about it.

Thomson also designed alternators. In 1886 he gave us the welding transformer, a most useful and important piece of apparatus used today in almost every factory. In 1887 he came out with his repulsion motor idea and I can say that here in America he was the first practical experimenter in alternating current. Professor Thomson also invented the recording wattmeter in 1888. Some of his patents were so important and fundamentally valuable in alternating current matters that they later on brought about a compact between the General Electric Company and the Westinghouse Electric Manufacturing Company.

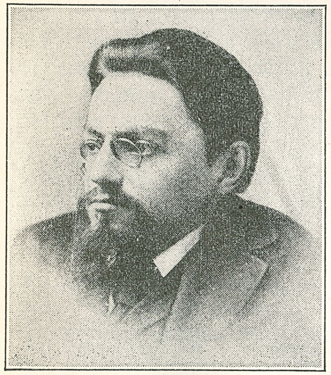
Among the bright young men that clustered about Thomson was E. W. Rice, Jr., who started in 1880 and rose to a high position with the Thomson-Houston Company and later with the General Electric Company. Rice was a fine engineer and inventor and also possessed a remarkable skill in management and administration, which qualities later on in years brought their reward as president of the General Electric Company after Charles A. Coffin had passed

E. W. RICE, Jr.

away. Rice was always an upright character with a genial disposition and was in every way an honest, selfmade man.(5)

Likewise, there were Axel Ekstrom, Henry G. Reist and A. L. Rohrer. When the General Electric Company came in 1892, other names were added, among which the most conspicuous was that of Charles P. Steinmetz. It is difficult to enhance the reputation of Steinmetz more than his name indicates to all of us. He was a profound mathematician, scientist and electrical engineer whose superb intuition converted abstruse mathematics into practical usefulness. He was a peer among the early veterans of alternating current, and his work in that direction gave special luster to the advancement of that art. Even before E. W. Rice brought him from the Eickemeyer Company to the General Electric Company, he was already distinguished as a coming electrical leader.

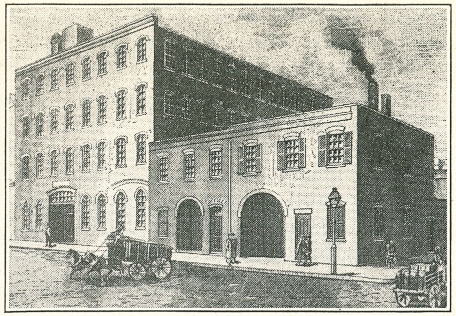
There were others also—James J. Wood, M. M. M. Slattery, W. M. Mordey, etc., who were clear observers on the alternating current problem in those early days.



CHARLES P. STEINMETZ

One of the peculiar characteristics of Steinmetz's nature was that he always did his best when he could work untrammeled by shop or office rules. Steinmetz had on the banks of the Mohawk River a work-nest (or 'camp'), and there he would go to solve his difficult problems. This camp building was presented to Mr. Henry Ford and can be seen in Greenfield Village.

(5) The death of Professor Elihu Thomson on March 13, 1937, leaves Dr. Otto Titus Blathy as the last survivor of the big ones that have remained on the job.



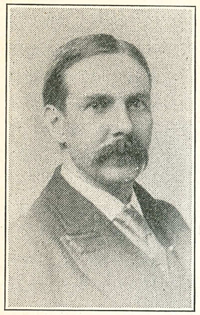
Edison Electric Tube Works, Bridge Street, Brooklyn.(1)

LXXXVI. Tubes, or Underground Conductors

FROM what has been related, it is evident that the Edison interests never contemplated staying in the electrical field. They easily could have taken up the subject of alternating current. At the West Orange laboratory was Dr. A. E. Kennelly, brilliant scientist, with practical experience obtained in England. He was a sort of scientific adviser to Edison, and consulting electrical engineer for the Edison General Electric Company. He designed alternators and transformers and conducted a series of experiments on alternating current for Edison. An old friend told me that Batchelor once just got a little nibble of the high-tension alternating current while the experimenting was going on, and it proved to be a 'knockdown.' What he saw would only interest astronomers.

The Edison General Electric Company also had a well-versed academical engineer who worked himself up to become chief electrical and mechanical engineer of the company. I refer to Dr. Emil Kolben. Just to show his mettle, when he returned to Europe in 1892 he started an electrical works in Prague, Czechoslovakia, that expanded rapidly. Today his

(1) This company was incorporated in January, 1881, with capital stock of $25,000. The first shop was on Washington Street, New York City, and afterward in Brooklyn for the 'manufacture and sale of electric tubes for conducting electricity.'



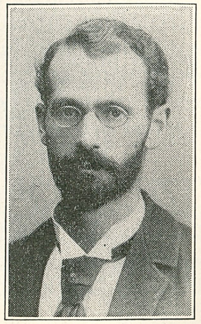
DR. E. A. KENNELLY

efforts form part of that great concern known as 'Ceskomoravska-Kolben-Danek,' where every imaginable thing is manufactured in the electrical and mechanical lines.

Kolben stands the third of those leaders that once worked in the Edison shop. First came Sigmund Schuckert, second Sigmund Bergmann, and third Emil Kolben. What would have happened if the initiative of a Bergmann, Kolben and Kennelly would have continued in the progressive electrical development of the Edison General Electric Company, with their vast previous experience. The past has shown what Schuckert, Bergmann and Kolben have done. The gods willed otherwise.

I shall not comment in detail on the serio-comic polemic that raged during the latter part of the eighties between the direct and alternating current partisans. Many serious discussions took place here and in Europe, and contradictory statements were made that seemed to indicate business motives were often the reason for this or that opinion. There was a veritable blizzard of camouflaged pamphlets full of recriminations, and the whole affair seemed to be what today one would call 'cut-rate propaganda' for one party or the other.

They were rollicking days. Infringers abounded everywhere, grabbing the fundamental principles embodied in the Edison patents, upon which the art was based that he had created in Menlo Park. Only a few years before, they had ridiculed in a most contemptuous manner his lamp and system, and as they became conscious of their mistakes and of the vast importance of Edison's greatest achievement, they swooped down like a flock of vultures.



DR. EMIL KOLBEN

Dummy witnesses, discarded old patents that were of no practical value, ancient lore, together with a great array of legal advisers, and everything that money could buy was tried to circumvent the Edison patents. The flaw

hunters never for a moment disagreed as to what Edison had done and created. They built their ambush behind words and legal technicalities, seeking like road agents to tap the Edisonian treasure chest within,—the ironical 'Legal Limits.'

No doubt, if the Edison Electric Company, which held and controlled the Edison patents, had adopted an amiable and conciliatory course, millions of dollars would have been saved. The Edison patents dominated such universal interest that they seemed almost a monopoly, and that violated the principle of 'live and let live.' The Edison Electric Light Company was for some years only a paper company, farming out its rights and concessions to Edison, Bergmann and others who in themselves only created. It formed a limited ironclad block whose principles were to buy lamps, machines and system only from us. That, of course, aroused the 'dander' of others. Many infringements and law suits resulted. Reasonable concessions and privileges to everyone that wanted only this or that would have obviated all this.

I believe that I am correct in saying that it required fifteen or twenty years for alternating current to reach that stage of proficiency in the development of service that is obtained from the direct current network in cities. As a transmission agent for long distances, alternating current never had a competitor from the start given it by the Hungarian inventors in 1885. Of late years it has been patterned after the Edison network and feeder system, and has established itself generally.

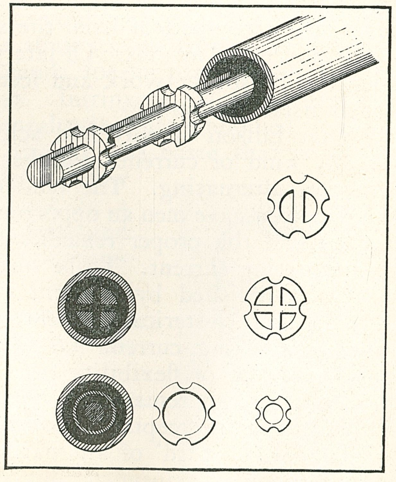
What Edison already had achieved was evidently good for any kind of current, whether for low or high-tension, direct or alternating. The fundamental paths that he had thrown open gave men an opportunity to specialize in the art, and to find the proper remedies for all the inherent antics of alternating current. To be sure, fine and great work had been accomplished by eminent engineers and scientists in curbing this 'hysterical' current. However, for motor purposes alternating current has not yet reached the highest possible grade of flexibility like that of the direct current motor, although remarkable improvements have been made to place it in an acceptable position for general purposes.

The 'trump card' of alternating current is the ease with which it can be transmitted long distances; the apparatuses employed in delivery are silent; moving parts and commutators are not necessary.

I have listed only a few of the fundamental patents that were granted Edison on the 'System of Electrical Distribution.' They suffice to illustrate how prematurely, and yet precisely, he had mastered the subject. He 'ploughed' ahead; he gave us the basic leads, in addition to his other grand achievements, that have placed the art of electrical engineering on a sound basis. The characteristics of his high-resistance lamp established all the necessary laws of electrical distribution.

Through the numerous patents granted him, Edison sought to specialize on the different aspects of those laws. His patents in electric lighting are special historical vouchers, attesting the enormous labors and concentrated efforts that the young electrician of Menlo Park experienced. Wonderful and mysterious were his ways; with adroit finesse he managed to take the ponderable and open paths for the imponderable, and render them serviceable to men.

The successful results of his labors gave impulse to all; men soon found that this self-taught genius of Menlo Park had opened vast fields of pursuits that were intellectual and practical. Yes, Edison's invention of the high-resistance lamp, the 90 percent efficient dynamo, the meter, socket, switches, fuses, the necessary adjuncts for making a complete system of domestic lighting, his system of current distribution, the conducting meshwork, feeders for high and low tension in both series and parallel work—all these great achievements were but one step toward the realization of greater cultural ideals that destiny had chosen him to lead others to accomplish.



Drawing from Edison's application for underground conductor patent. Signed April 22, 1881; granted December 27, 1881; No. 251,552.

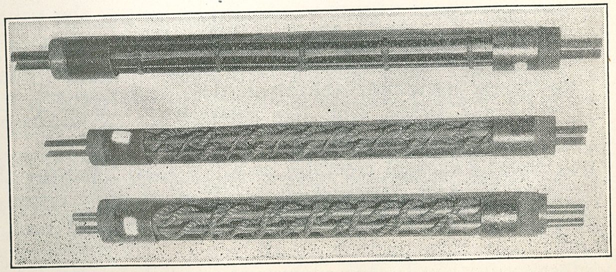
For city lighting he had to invent practical

underground conductors. Nothing existed in his established line of work that he could use. There was no precedent.

Early in 1881, Edison gave considerable thought to a system of underground conductors. The master patent specification for this system was signed on April 22, 1881. The patent was granted December 27, 1881, under No. 251,552. The insulating compound Wilson S. Howell had made when he laid the underground conductors for the Menlo Park demonstration in 1880-81 served as the insulator in Edison's underground tubes. The composition of this was refined Trinidad asphaltum, boiled in oxidized linseed oil with paraffin and beeswax.

The underground conductors consisted merely of copper bars with pasteboard washers slipped over them—insulation and an iron pipe protecting them. In New York City the half-round form was first employed, connected with the two-wire feeder-system first installed in the Pearl Street Central Station. The millboard washers were slipped over the two copper conductors and held at equal distances by cord. When the washers were firmly held in place by the cord, the whole was slipped into a wrought-iron pipe. One end of the tube was placed in the hot asphaltum compound; through a suction hand-pump, the insulation compound was raised to fill the pipe.

It will be noticed that the washers were stamped out to leave intervening spaces, through which the insulation compound passed, filling the pipe and keeping the copper-conducting bars in the center. The connections between each of these tubes were made by 'U'-shaped connectors, which served



Evolution of Edison's underground conductors. Top—Washer method; Center—Rope method; Bottom—Improved rope method.

not only to unite the copper bars electrically but also to absorb their expansion and contraction because of changes in temperature. Encasing these 'U' connector pieces was a suitable cast-iron junction-box. When the connecting was completed, the box was filled with the insulation compound.

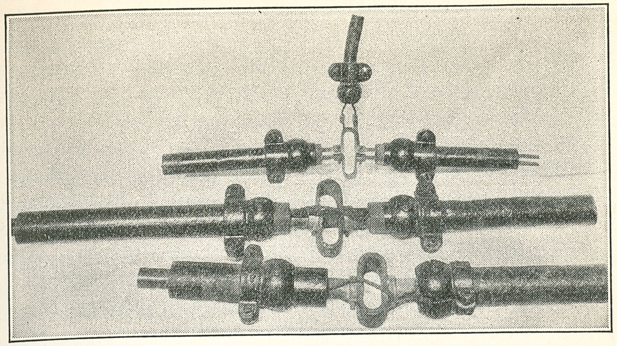
It may be well to mention here that in the feeder mains Edison placed auxiliary wires, called pressure wires, connecting the central station with the points of supply. Through them he was able to measure and regulate the pressure at any of these points. In that manner it was possible to maintain a constant pressure throughout the entire network (or rather at the different points where the feeders supplied current into the service mains) whether to lamps nearest the central station or to those most remote.

The copper conductors, twenty feet, four inches long, projected at each end from the iron pipe. The wrought-iron pipes were about twenty feet long for the smaller-sized ones. Iron pipes of larger diameter, with copper conductors of greater cross section, were slightly shorter to provide ample projection length of the copper bars for connection purposes.

In the development of this system of underground conductors many difficulties were encountered but all were successfully overcome. There were the junction boxes, boxes for house connection service, safety catch box, fittings and other adjuncts—all had to be worked out and then made in various standard sizes.

In this work Edison was greatly assisted by John Kruesi. On February 14, 1881, Kruesi left Menlo Park permanently to start the Edison electric-tube factory at 65 Washington Street, New York. Kruesi's conscientious work in this line must never be underestimated; he not only directed the factory but also spent nights with Edison laying the tubes in the streets of lower New York, while the erection of the Pearl Street Central Station was in progress. Among the many annoying incidents which Kruesi experienced while making the first tubes was the appearance of air-bubbles in the insulating compounds.

When these physical troubles arose, Kruesi brought them to Edison if he had not already noticed them. From the 'pow-pow' that resulted, matters were soon ironed out. In the mechanical construction of all accessories pertaining to the underground conductor system, honest John Kruesi was given 'carte blanche,' subject of course to Edison's approval.



Early specimens of Edison's underground conductors for two-wire system. Top—Service main showing branch off for consumer's connection. Middle—Feeder line showing the galvanometer or pilot wires. Bottom—Heavy single conductor with pilot wire. Junction boxes are not shown.

Later, the cardboard washers were replaced by rope-winding as the self-explanatory photographic illustration shows. The 'U' expansion or contraction joints were replaced by flexible copper cables. I might mention here that thin copper corrugated bands in multiple were also tried as coupling joints, but the copper rope ones proved the most practical.

When the three-wire system came, the conductors in the iron tubes were changed to round copper bars, thus affording better electrical joining facilities. Edison's underground tubes had a copper cross section ranging 80,000 to 1,000,000 circular mills. The illustrations show the cross section of different sized tubes and fittings that were made for the two and three-wire system.

Christian G. Rach still lives and remembers the various stages of pioneer work that Edison went through when he began making the underground electric tubes at 65 Washington Street, New York City, in 1881. On September 27, 1881, he was engaged by Kruesi and, in 1883, when Edison moved the works to 18 Bridge Street, Brooklyn, Rach followed.

About this time the Electrical Tube Company was absorbed by the Edison Machine Works. The armature department of the Goerck Street Works was moved to the new quarters in Bridge Street where more space was available for this special work. In 1885 Edison installed machinery for the

manufacture of wires and cables and here the first practical braided and flexible electrical conductors were made for incandescent lighting wiring. The first Edison underground tubes for the three-wire system were made in the Bridge Street Works.

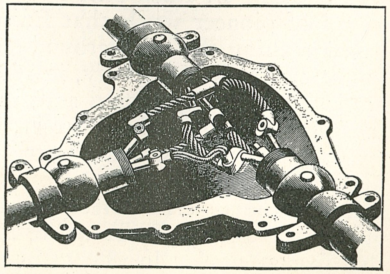
In the latter part of 1886 Edison began to move his works from New York City to Schenectady, New York. Rach was one of the last to leave the Bridge Street shop. In Schenectady, Kruesi put Rach in charge of the tube department, and after the Edison industries were merged into the General Electric Company in 1892, Rach remained and continued to head the tube department until the last Edison electrical underground tube was made, September 22, 1922.

The Edison underground tube system was the most important of its kind during the early pioneering days; in fact, it has held its own for many years in the fore part of the present century.

The great work that Edison executed at Menlo Park in giving the world the many insights to the distribution and transmission of electrical energy for useful purposes has never been fully brought forth. The whole system of transmission lines and electrical networks of the world is based on the patents, which drawings I have illustrated. The principles that Edison enunciated on this subject have long since been acknowledged. Yet I remember when they ridiculed him, saying he knew little about the subject. Some said that in the world there was not enough copper to light a small town.

When he demonstrated his 90 percent efficient dynamo, his practical lamp, and his systems of current transmission, they cried, 'Oh! that's the way you do it, we did not know that.' At last they said, 'that's all right.'

Mathematicians acquired bread for new thought; the books they wrote on current distribution and networks were sufficient to give one a headache. They gave us laws about

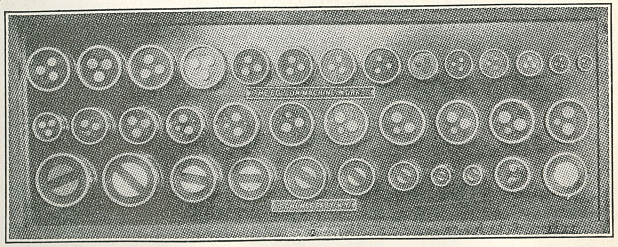


Edison coupling-box, tee-branch type, showing flexible copper cables in place of the solid U-type.

using copper (ask the 'boys' in the great electric light companies what they do now). Experience has determined in a practical way what to do in these ever-changing conditions. All companies employ standard sizes for mains and feeders, and when necessity demands another feeder in a section they lay this or that size of feeder. In some cases they may split the feeder of a main into different parts, thus increasing the conductivity. Theory always bases its arguments on fixed facts; however, practice changes them constantly.

Edison, with his vision, worked out a complete system long before others dreamed such a thing possible. His great system was new; it was universally useful and essential to his fellowmen. In Menlo Park he had crossed new and unknown frontiers, opening a vast continent full of the greatest expectations ever imagined. He had awakened men in all walks of life; his energy spurred them to a new kind of activity; humanity reaped the benefits of Nature's great force, not yet exploited. The domains into which Edison penetrated were vast and overwhelmingly resourceful; it seemed impossible for one company to retain so much. Edison's deeds daily become more lustrous as they afford usefulness and comfort to the generations.

Milliken said that Edison 'probably exerted a larger influence on man's life than any political leader who ever lived.' He said further that 'Edison, through the phonograph, through his part in the development of the cinema, through his work on the electric light, and through the Edison Effect Tube, which underlies much of modern wireless, helped



Cross sections of Edison underground electric tubes. On bottom row are mains and feeders of the two-wire system, including heavy feeder conductor on extreme right. In center row are feeders of three-wire system. Note smaller diameter of the neutral, also the pilot wires. Top row shows mains with wires of equal bore for positive, neutral and negative poles.

to knit the world together so that ideas travel now as they never traveled before. Henry Ford says, 'We live in the Age of Edison.'

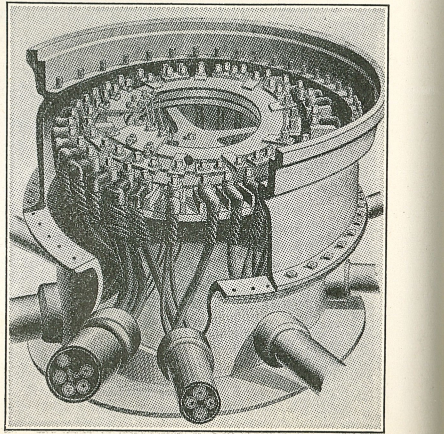
Several times I have emphasized the fact that Edison had a Faraday conception of what watts, or electrical energy, were, long before the watts were known as such. His invention of the first practical electrical incandescent lamp for domestic lighting not only proved that, but embraced the very laws of power transmission and current distribution.(2)

Some notes written by my old colleague, Charles L. Clarke, at the time, will serve well as a conclusion to this discussion of the subdivision and transmission of current:

'The whole trouble was that most of us at that time did not know that webers (today called amperes) x volts = energy (today called watts). It was believed that the stronger the webers (also spelled vebers) the greater the energy, and in a certain sense this was right. Edison, however, employed tension (that is, volts) to overcome resistance, or equivalent, and thereby made electricity a commercial commodity for sale to many customers for use in electrical devices distributed over wide areas. Thus when he found that a lamp of 10 webers at 10 volts required 100 times more copper than a lamp of 1 weber at 100 volts for the same loss of energy in the transmission line in both cases, most men could not understand it.

'The light given out by both lamps was practically the same, for the energy consumed was equal; yet few understood how to "juggle" with webers and volts to produce the same effect with the least quantity of current.

'Edison's ideas were far in advance, and his able mathematician,



Early Edison street safety catch box used for protection of underground conductors.

(2) See Volume One, page 255.

Francis R. Upton, translated them into figures. As I have told you, Upton at first did not understand, but Edison in his own way, using matches to illustrate his points, soon convinced him.

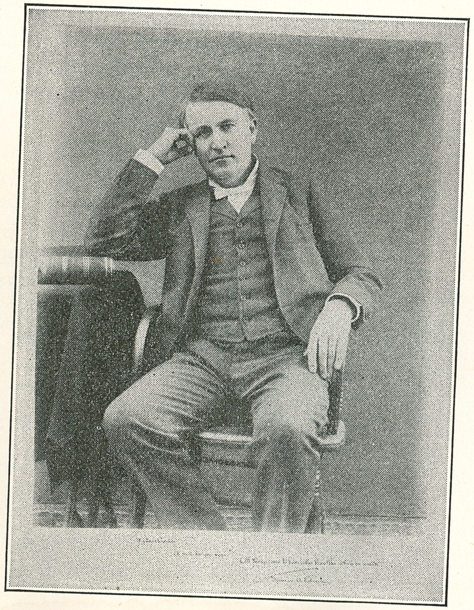
'Upton put it in algebraic terms, as follows: Denoting the current by C, volts by V and resistance by R, we have $C = \frac{V}{R}$, which is Ohm's law. Further, denoting length of transmission line by L, and cross section of wire for the line by S, we have $R = \frac{aL}{S}$, in which *a* is a constant, the value of which depends upon the character and quality of the metal used, which practically always has been copper. Substituting this value of R in the equation for Ohm's law, we have $C = V \div \frac{aL}{S}$, from which $S = \frac{aCL}{V}$—that is, other things (except the electrical characteristics of the circuit) being equal, such for example as loss of energy in the wire, its cross section, and therefore, weight for equal lengths, varies directly as the product of the length by the current, and inversely as the voltage.

'Here is the fundamental law for the transmission of electrical energy as it was first expounded by Edison. Let me give you an example—take a lamp with 10 webers and 10 volts and find the cross section of wire required to transmit energy 1,000 feet at any given percent loss of the total energy supplied. Noting that we are only interested here in obtaining *relative* values (thus neglecting the constant *a*), and substituting the foregoing figures in the last equation above, we have $S = \frac{\text{10 webers x 1,000 feet}}{\text{10 volts}} = 1{,}000$.

'Then take a lamp of 1 weber and 100 volts, and the same length of wire and energy loss therein, and we have $S = \frac{\text{1 weber x 1,000 feet}}{\text{100 volts}} = 10$, which is 100 times less cross section than before; therefore, 100 times less weight of metal needed for the lamp working on 100 volts and 1 weber than for the one consuming 10 webers at 10 volts.

'From Ohm's law and such examples as those above, Upton stated a simple relation of cross section of transmission lines of equal lengths, and with equal losses of energy in

them, to the resistances of lamps respectively supplied by them. Taking the first example, in which S is 1,000, we find from Ohm's law that the 10 webers divided by the 10 volts (or $\frac{C}{V} = \frac{I}{R}$) = 1, while in the second example, in which S is 10, or 100 times smaller, 1 weber divided by 100 volts is $\frac{1}{100}$. From which it follows, as Upton first showed, that the lamp resistance varies inversely as the transmission line cross section. That is, a 1 Ohm lamp would require 100 times more cross section of metal in its line than a 100 Ohm lamp, consuming the same energy, for the same loss in transmission.'



EDISON in 1889.

LXXXVII. Menlo Park in 1880

(1) By CHARLES L. CLARKE

ONCE upon a time, which is to say fifty-three years ago, when Edison with his dynamo and incandescent lamp had just demonstrated to the world that electricity was about to do our lighting in place of gas, the wheel of spiritual good fortune landed me in the great inventor's laboratory at Menlo Park, New Jersey.

Being still on earth, 'of sound and disposing mind and memory,' I am asked to reminisce a little on how this wheel rolled me into Menlo and what part I played in the laboratory life of the small band of eagerly ambitious and loyal assistants there.

Let me tell my story with the least possible bragging about myself that is consistent with human frailty coupled with unavoidable pride at having worked for, and intimately with, the renowned Edison at Menlo Park.

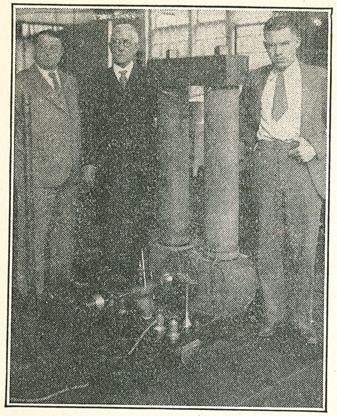
Upon completing the high school course in Portland, Maine, in 1870, I worked my way up to the position of assistant division engineer of railway construction in the Boston-Portland section of the old Boston & Maine Railroad. In 1875 I was graduated in civil engineering at Bowdoin College.(2) After a subsequent inspection trip abroad, I faced a future that seemed rosy to my youthful mind. But alas! the Black Friday gold panic of 1873 brought on by Jay Gould culminated in such a financial depression that the hitherto rapid extension of railroads in the West came to a stop, the majority of civil engineers were thrown out of jobs—and of course there was nothing for me! I found work for a while as a draftsman under the noted Alex. L. Holley, consulting engineer on steel and rolling-mill equipment and operation. This job soon ended because of tight money. I next found myself teaching school at Cheltenham Academy, near Philadelphia—glad of board and lodging and especially the eighty-dollar-a-month pay. I knew well that I was not cut out for teaching and I chafed at the work, keeping a lookout meanwhile for a job suited to one with an inclination for engineering and the related sciences.

For some time past a college classmate and close friend of mine, Francis Robbins Upton (who had taken a post-graduate course in science at Johns Hopkins University and had later studied under the famous Helmholtz at Berlin University), had been with Edison, nominally as his mathematician but in fact doing anything that the Edisonian moment demanded like all the other assistants there—one day working with pencil and paper and the next day mucking with chemicals and machinery up to the elbows in dirt and grease.

In the course of our frequent and intimate correspondence, Upton wrote to me from Menlo Park on December 2, 1879, as follows: 'I feel quite badly that you did not come to see me or let me know that you thought of going to New York; for I should like to have a talk with you. My advice is not to accept

(1) At my request, Charles L. Clarke has contributed his reminiscences of Menlo Park in 1880. As a friend of Upton's, Clarke entered the laboratory early in 1880 and in 1881 moved to New York to become chief engineer of the Edison Electric Light Company. The paper was written in 1933.

(2) I received B.S., on graduating, later M.S. and still later C.E.



Left to right—C. J. LEEPHART, C. L. CLARKE and W. A RUTH.

any situation under the American Union Tel. Co.; it is a stock jobbing affair got up to sell out to the W. U. Tel. Co., and will probably last only a few years . . . I am glad that you have made up your mind to go into business and fall in line with the money makers (*sic!*); for I think I have a chance here for you. Between you and me, Mr. Edison has found a most elegant light which is going to be largely used; and to put it up properly will require a large number of young men with theoretical training. The finest problems in steam engineering are involved and the highest state of electrical science. My candid advice is for you to come immediately to Menlo Park not asking any wages . . . We shall give an exhibition here in the course of a few weeks . . .'

On December 23 he wrote to me at Portland where I was spending the holidays with my parents: 'Edison says he will give you $12.00 a week, and you can commence at any time . . . You must come—it is the chance of your life. Remember me to your parents.'

And again, on December 31: 'Come here by all means on your way back (from Portland to Cheltenham Academy) and make the strongest endeavor to stay. I am glad that you have accepted and think it will be a fine chance for you.'

And so on Saturday, January 3, 1880, on my way back to school-teaching I stopped off at Menlo Park and was made welcome at Upton's home by his beautiful wife, the lovely and dainty Lizzie Perry, of our college town and days. Upton showed me through the laboratory, the machine shop, the office with its large scientific and technical library, besides introducing me to Edison, who happened to be testing his transmission dynamometer in the machine shop. The latter immediately drafted me into service as a handy helper to shout the time by my watch for starting and stopping his speed indicator. As darkness by and by came on, wonderful little Edison horseshoe lamps with carbonized Bristol board filaments began to glow here and there in the laboratory establishment, in a few homes and on the outdoor lamp-posts. Upton was enthusiastic. As he took me into his parlor to see two lights on a ceiling fixture burning with perfect steadiness and giving a pleasing illumination to everything in the room, he exclaimed dramatically: 'Charlie, those lamps should last forever. The carbon is in a perfect and permanent vacuum and cannot be destroyed!' And yet the carbons *were* destroyed. The filaments did not burn up, it is true, but they finally broke. And how fortunate that those lamps did not last forever—nor yet the improved lamps of today! It is sufficient that they last long enough to be of great utility to mankind. Suppose they should last forever and, just as reasonably, suppose railroads, ships, automobiles, all the little every-day appliances, and even clothing should last forever—why, the human world would become static, mentally petrified and physically mummified!

Upton took me back to the office, hunted up Edison, and bringing him in said: 'This is the friend I have told you about. He is a better mathematician than I am.' With his genial little smile, so well known, and his quick direct manner, Edison jerked out: 'All right—glad to have you come—give you twelve dollars a week.' I expressed my satisfaction. A pleasant nod and a handshake closed the transaction—and Edison was gone—back to his problems in the laboratory.

The next day I was again in my chair at the academy to work out the month stipulated in my notice previously given the principal. It was a strenuous month, what with school duties all day and studying until past midnight from Sprague's book (3), *Electricity: Its Theory, Sources and Application* in hurried fundamental preparation for the coming work at Menlo Park. For I knew nothing about the practical applications of electricity. Even manipulation of the Wheatstone bridge so essential in electrical work was beyond my experience; indeed, I doubt whether I then knew that such an instrument existed.

While I was thus busied in Cheltenham, Edison in Menlo Park seemed to have been uneasy about my delay in arriving. For on January 15, Upton wrote. 'We want you to hurry up and come; there is plenty for you to do. The main thing is to figure on sizes of conductors and methods of distribution. T. A. E. wants me to say that the sooner the better.'

Everything has an end, it is said. Thus fatefully the month reached its end, and Sunday, February 1, 1880, found me again at Menlo Park with lodgings over the kitchen in the L of the home of farmer Thornall and board at Mrs. Jordan's next door where I had the company of other young and some of them very lively fellows of the laboratory.

Several months later when the hamlet had become crowded because of the increased number of workers I changed boarding houses, joining the more sedate men at the Woodward home down near the station across the Pennsylvania Railroad tracks.

The very Sunday of my arrival saw the beginning of my work. After a supper at Mrs. Jordan's I repaired to the desk assigned to me on the first floor of the office building and began calculating a table of useful constants for copper wire according to the Birmingham gauge. This work I surmise only served the purpose of getting me started and accustomed to new surroundings; for the calculations soon stopped unfinished, and after all, they were unnecessary because there were already good tables of the same character in print.

About midnight, just as I was beginning to feel lonesome at my solitary desk, a head popped in at the rear door and its owner bade me come to the laboratory. There on the second floor away back near the pipe organ sat Edison, and scattered about were the night-working assistants and helpers—all, however, within convenient reaching distance of hamper baskets loaded with good things to eat that had been brought from Woodward's—not a cold lunch, mind you, but a hot dinner of flesh or fowl with vegetables, dessert and coffee! Hilarity increased with the filling of stomachs, bantering and story telling were interlarded. At length Edison stood up, stretched, took a hitch at his waistband in sailor fashion and began to saunter away—the signal that dinner was over, and work would be resumed. This my first night meal in the laboratory was the occasion for testing my fitness to join the brotherhood. I passed examination and was initiated with a few happy remarks by the great master himself.

Before long my headquarters were shifted from the office to the laboratory where I was given a table on the west side of the room near the organ. This

(3) London 1875.

location proved interesting; for here Edison would sometimes come to relax himself with strumming on that instrument, staccato fashion with a forefinger —which performance, I assure the reader, helped to let down the mental pressure of all within hearing.

My first real electrical experiment took place a few days after my arrival at Menlo. The laboratory was at that time lighted with lamps in ceiling fixtures. It happened upon this occasion that a lamp mounted in a wooden stand on a table was undergoing a life test. Of course, I was inquisitive about everything so new to me. Innocently I picked up a short piece of copper wire that was lying on a table near by, and holding one end of it against one binding post of the lamp stand I gingerly touched the other to the second binding post, merely to see how the brightness of the light would be affected. I never before realized that electricity could be so quick. In less than a jiffy a sputtering spark at the contact between the wire and the binding post and a hiss overhead as from a spitting cat made me jump. The wire connection was broken! To my surprise the lamp was not only out but remained out until a melted lead wire fuse (then called a 'safety catch') in the lamp supply circuit overhead had been replaced. The experiment was a good joke to the others, especially to Edison. I forthwith learned from him what constitutes short circuiting, why it occurs, and how it can be avoided. Yes, in a few minutes I learned a lot about the multiple-arc lighting system, information that was timely because it put me on the right track practically at the start.

Laboratory life with Edison was a strenuous but joyous life for all, physically, mentally and emotionally. We worked long night hours during the week, frequently to the limit of human endurance; and then we had time off from Saturday to late Sunday afternoon for rest and recreation. Our activities were all thus co-ordinated to fit the habits of work of the central originating and guiding mind and personality.

The psychological atmosphere of the place partook of the inspirational as a sort of reflex from Edison's genius, which was happily joined with a common sense and a sane human nature that made him 'one of the boys'—mightily for his own good as well as the good of those about him. Here breathed a little community of kindred spirits, all in young manhood, enthusiastic about their work, expectant of great results; moreover, often loudly explosive in word, emphatic in joke and vigorous in action. For isolated as they were in the monotony of a rural neighborhood, they were sometimes under the pardonable necessity of 'working off steam' for very safety.

Let me here digress from my immediate story to mention Charles Batchelor, the chief assistant who was with Edison before his removal from Newark to Menlo Park, and whose name should not be left out of any account touching the laboratory life there. It was my good fortune to have a table next to his in the laboratory, and though our work was not of the same nature we often found ourselves mutually helpful. I welcomed the association with this genial, fair-minded and able man.

My memorabilia of 1880 indicates that on February 12 Edison started me experimenting with the expansion or contraction, as the case might be, of carbonized Manila fiber when used as a lamp filament. This work was followed by investigation of the capillarity of chalk cylinders for the motorgraph in the loud-speaking telephone; calculation of a candle power scale for a new Bunsen photometer; calculation of the wall illumination of a room of stated dimensions when lighted by gas jets and when lighted by the Edison lamps under specified conditions; calculation of the all-round candle power of the horseshoe lamp with carbonized Bristol board filament (the spherical photometer was as yet unborn); development of a sensitive device for quick weighing of lamp filaments; investigation of the carbon deposit in lamp bulbs, especially with respect to images produced by the intervening filament legs and the clamps for fastening them to the leading-in wires; investigation of telephone diaphragm vibrations by means of the well-known powder figures; calculation of the merit of Edison's feeder-and-main system of electrical distribution in saving of copper as compared with that of a straightaway distributing system without feeders, in which lamps are supplied all along the system from its connection with the central station source of electricity to its outermost ends.

I was constantly observant of all that was going on about me, *working and studying overtime*, as the ambitious young should ever do if they expect to move onward and upward. I was beginning to grasp much of what was then known about practical electricity. The Wheatstone bridge, the Thomson mirror galvanometer and other electrical apparatus about the establishment became old friends for understanding and use. I was delving into the mysteries of the construction and operation of Edison's dynamos, which I first saw in early January. I was interested in their installation on the Steamship *Columbia*, of New York, as part of the first commercial Edison lighting plant, and when that ship started regular service on May 2 I witnessed the send-off. Of course, dynamos of this sort were in operation day and night at Menlo Park. My work in dynamo design came somewhat later.

Edison's central station system of lighting with distribution by underground conductors looked promising as thus far tested and developed. The men financing the enterprise, which was fathered by the Edison Electric Light Company, desired that a complete operative system be installed on a suitable scale for testing the economy of the system and uncovering weak spots if any existed inherently in mere bigness, before they should risk much money in commercially exploiting it.

Installation of this trial system at Menlo Park was soon under way. I was called upon to calculate the sizes of the underground conductors on the basis of a 10 percent drop in voltage from the central station to the outermost limits, with a full load of lamps on the system. The total length of underground circuits was 39,000 feet, of which the longest was 3,800 feet. It was a simple straightaway distribution without feeders, which were unnecessary in this trial.

The conductors were built up of the requisite number of strands of Number 10 Birmingham gauge copper wire and bound together with a wrapping of homemade insulating tape. They were laid in wooden box conduits in trenches along the side of the grass-grown streets of the place. A hot tar compound was poured over them for better protection, the conduit covers were put on, and the trenches refilled. Underground taps were taken from the conductors to the wooden lamp-posts along the streets. I well remember the hot, mussy, tedious work of laying those conductors that summer and fall!

Early in the year Edison began the installation of an electric railway. The first trial of the system was made on May 13. Of course, as a civil engineer I watched its building and operation with great interest. I cannot say that I had much to do with it—though I sharply recollect that in John Kruesi's office in the machine shop I was the center of a lively discussion into which half a dozen others pitched, Edison included, regarding the merits of a worm gear drive in the electric locomotive for regulating the high-speed armature to the locomotive driving wheels. I was opposed to the device. It was tested out, though under unfavorable conditions, and was not used. Non-locking worm

gear drive was not then the efficient mechanism that it soon became for certain limited applications in power transmission.

About midsummer Edison put me seriously to work on the design of a special bipolar dynamo to be driven by a Porter-Allen high-speed engine directly connected with the armature shaft. The dynamo was to be of far greater electrical capacity than those previously made; and copper bars were to be used for the armature coil winding instead of stranded insulated copper wire. The designing of the bars on the armature ends for the purpose of connecting the bars on the armature face with each other and with those on the commutator proved exceedingly complicated and the parts difficult to make and assemble. Nevertheless, the machine was made. Tests in the winter showed that the engine was not adapted to running continuously with safety at the 650 revolutions a minute for which it was intended and that because of insufficient ventilation of the armature bars, especially at the ends, the current capacity was too low.

The first real tryout of this dynamo awaited the presence of Charles T. Porter, the noted builder of the best class of high-speed steam engines in use at that time. How well I remember the night of the test. Edison, Porter, Kruesi and our Scottish engineer Jack Hood were there, and an interested lot of laboratory assistants and boys watched through the windows from outside the engine room. Porter was at the throttle, I held the speed indicator and Edison held the watch. The engine and armature turned—very slowly at first, and then faster and faster until the governor took hold and all the moving parts became a blur like that produced by flies' wings: a newspaper could be foggily read through them. The noise simulated that in the forge shop of an old-fashioned shovel factory—it was terrific.

'Hup,' yelled Edison, and in went the speed indicator point; 'Hup,' he shouted at the top of his voice, and out it came—750 revolutions a minute!

Edison already had a new idea for improving the bar-wound armature. He proposed substituting insulated copper discs, one laid against the other at the armature ends, in place of the complicated bar connections before mentioned. The discs had projecting lugs on their circumferences for connecting the bars on the armature face with each other and with the commutator. The arrangement was simple in design and easy to construct. It was first applied to the armature of one of the regular fifty-light 'A' dynamos which was tested in December. These bar armature investigations led to the development in 1881 of the direct steam-driven 'Jumbo' dynamos, one of which was exhibited at Paris that fall, three in London in early 1882, and six were installed in the first commercial Edison central station at 257 Pearl Street, New York City, which started operation on September 4, 1882.

This 'Jumbo' development came after the close of the spiritually Edisonian days of Menlo Park. The inventor was living and working in New York City on the commercial development and exploitation of his electric lighting system and only occasionally went to inspect the relatively small activities of Menlo Park, which place was now nine-tenths deserted.

It was in early December of 1880, as I judge from old data, that an accident happened which was quite disconcerting, doubtless not so much so to me, as to Edison's assistant Francis Jehl. The accident occurred during a dynamo test in the machine shop or the central station annex and resulted from some wrong circuit connection made by me which caused a coil in a valuable Wheatstone bridge in the laboratory to burn out. Jehl fairly loved that bridge (made by Elliott Brothers, London) from long association with it, especially in use with a Thomson mirror galvanometer and standard Daniell cells for the

measurement of voltage—the only means we had for this purpose until good direct-reading voltmeters were developed some years later. Well, when Jehl rushed in from the laboratory to tell me of the disaster with fear in his eye (and shall I say a little anger?), I lost all appreciation of my guilt in a feeling of sympathy for his distress—and it was, indeed, no joke. Well, he rewound the spool with new wire as best he could and the bridge was again good enough for all laboratory purposes. Jehl remembers the incident so well that he twitted me about it not long ago. I have not yet heard him say that the spirit of forgiveness has entered his soul. But knowing him as I do, I am morally certain that it has.

The laying of underground conductors as part of a small trial central station lighting system has already been mentioned. While this was going on, eleven 50-light 'A' dynamos were being made in the machine shop; a lean-to shed annex was built for a central station in which to set up the dynamos; countershafting, pulleys and belts were installed for running them from the eighty-horsepower Brown shop engine; a large number of wooden lamp-posts were erected, and complete wiring was installed in the laboratory buildings, the few dwellings of the place and the railroad station. All was enthusiasm under Edison's energetic and confident spirit.

A public exhibition of Edison's light at Christmas time in 1879 had interested and amazed the world. That the lamp had come to stay was certain. And now the approach of the 1880 Christmas season found the trial central station in full operation lighting up Menlo Park and the surrounding snow-covered fields in readiness for the flood of visitors that was sure to come during the holiday season.

Edison and his financial backers were only incidentally interested in curiosity-seeking visitors. Edison wanted above all else at this time to demonstrate to his backers that his electric lighting system was so economical as to rival and even excel the gas system.

Partly to this end he gave me the job of planning and supervising a comprehensive economy test of the system at Menlo Park. The test was to begin with weighed coal and water at the boiler end of the test and terminate with lamp candle power at the other end. The necessary intermediate physical observations would also be made, including, of course, the horsepower performance of the engine and the electrical output and efficiency of the dynamos.

A goodly number of observers was necessary; these were selected from laboratory assistants and others in accordance with the work expected of them. A preliminary twelve-hour test was had for the purpose of drilling all observers in their duties so that there should be no likelihood of incomplete data or total failure.

After the whirlwind of Christmas holiday visitors had subsided, preparations were made for the formal economy test upon the results of which the future policy of the Edison Electric Light Company should depend. It was an open, official test, made so by the invited presence of George H. Babcock and Stephen Wilcox, makers of Edison's Babcock & Wilcox boiler, Charles H. Brown, of Fitchburg, Massachusetts, builder of Edison's Brown engine, a few other engineers, the editors of the *American Machinist*, the directors of the Edison company, and persons financially interested in the enterprise.

There was no secret to hide nor information to withhold during the test; all visitors went where they pleased, saw everything and watched the observers record readings of apparatus, indicate the engine, and so on. With a full lamp load on the dynamos equivalent to 425 lamps of sixteen candle power, the test

continued from Friday night at 9:30 until Saturday morning at 9:20 of January 28-29, 1881.

The results of the test were rendered by me in a formal report dated February 7, 1881 (first published in *Edisonia*, in 1904). A preliminary survey of the outcome of the test must have been immediately satisfactory to Edison and his backers in the Edison Electric Light Company. For in two or three days (on February 7) Edison, boiling over with energy and enthusiasm, rushed to me shouting: 'Come on, Clarke; pack up at once and come with me to New York. We're going to begin business right off!' That very noon we walked into the 'brownstone front' at 65 Fifth Avenue which forthwith became the first commercial offices of the company.

Edison rushed me up to the second floor. 'The company has made you chief engineer,' he said. 'This is your office; the furniture will be here this afternoon. Furniture for your living room upstairs will be here, too—I want you on hand all the time!'

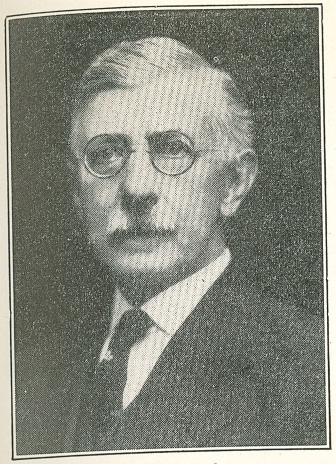
And thus on February 7 my Edison-Menlo Park days ended. Thereafter I used still to go to the old place once in a while because I had two or three men there on special work; but I found the buildings practically deserted and stripped of equipment—and Edison no longer there. To me the spirit of the great inventor had left.

Edison has always called himself an *inventor* and nothing else; and he best knows that inventor is fundamentally what he has always been—not a deviser of fugitive gimcracks but the creator of utilities of such value that they continue to this day profoundly to affect the ways of civilization to the betterment of mankind.

On occasions when some serious obstacle would stand in the way of advancement of our work on various developments it was always Edison who came to the rescue with a ready invention. Assistants in general chiefly served his purpose accordingly as they fell into line with his ideas from day to day and did not delay progress by getting sidetracked on dreams of their own that did not harmonize with his urgent plans. Of course, if an assistant was seized with an idea leading to a practical improvement, Edison was open to receive and adopt it.

Here is an illustration of this side of Edison's personality: One night, while I was at my table alone in the laboratory, he strolled in, took a chair, and for a time sat tousling his hair without saying a word. Of course I did not speak either. By and by looking up he said: 'Clarke, Doctor So-and-So is a fine fellow. He knows a lot, but he doesn't stick to the job. I set him at work developing details of a plan. But when he happens to note some phenomenon new to him, though easily seen to be of no importance in this apparatus, he gets sidetracked, follows it up and loses time.' Then with much emphasis: '*We can't be spending time that way!* We have got to keep working up things of commercial value—that is what this laboratory is for. We can't be like the old German professor who so long as he can get his black bread and beer is content to spend his whole life studying the fuzz on a bee!'

Long ago, the noted astronomer Simon Newcomb, condemning what seemed to him a too rapid growth of elaborate equipment in university laboratories, humorously remarked that so far as his observation went useful accomplishments seemed to be in inverse proportion to the elaborateness and expensiveness of the apparatus used to develop them. Newcomb's aphorism has worthy application to the Menlo Park laboratory out of which with the simplest and in general the cheapest sort of apparatus, largely of makeshift character, Edison's genius rolled one great invention after another of surpassing utility.



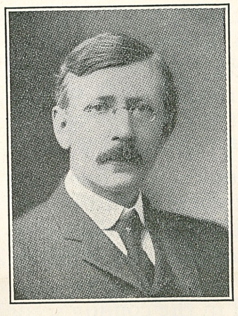
CHARLES L. CLARKE in 1933.

He counted on the ingenious working of gray matter in the brain given us and its use of the material facilities immediately at hand as of paramount importance, after which the addition of other apparatus might be of value if results already obtained justified it.

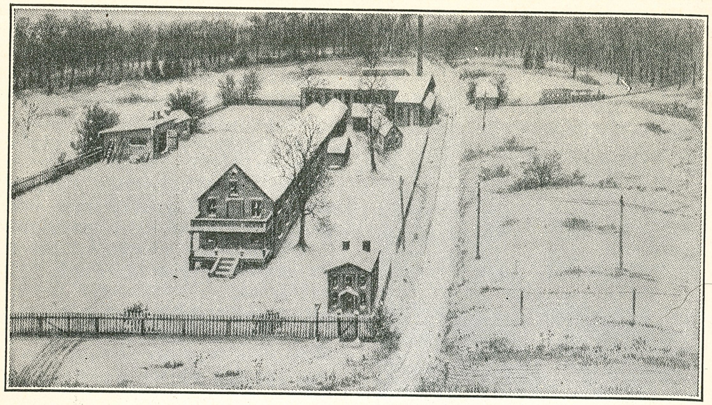
This point of view may be illustrated by another Edison incident: One midnight as I was passing through the metallurgical room of the laboratory where filaments were carbonized, I came upon Edison sitting alone, disheveled and tired. 'Oh, Clarke,' said he, 'sit down. What do you think—Doctor Blank (not the one previously mentioned) thinks he can make diamonds! He wants a platinum deflagrating tube for the experiment. Why, man, it would cost twenty-five hundred dollars! If only he could give us some tentative results with a porcelain tube to warrant getting a platinum one, it would be all right.' A minute of tense thought with uneasy hitching about and tousling of hair—then solemnly: 'No man can become an inventor unless he can do everything with a jackknife and a bean pot!'

And now in my vision of the past, darkness as of fifty years ago has given way to bright morn. Edison is sleeping curled up on a laboratory table. Work awaits another night. We assistants steal quietly off to our beds—tired out.

My story is told.



CHARLES L. CLARKE in 1903.



Menlo Park in winter of 1880-1 as painted by R. F. Outcault.

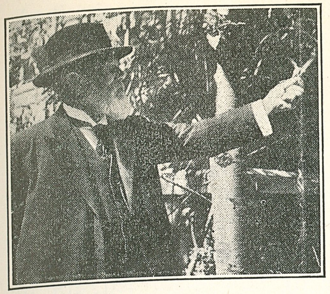
LXXXVIII. The Jumbo Dynamo—Its Beginnings (PART ONE)

DURING the late months of 1880, work at the laboratory changed in character. The bamboo lamps slowly turned out in the factory by the railroad tracks were given different kinds of tests. There were life tests, during which the lamps were under current at sixteen candles; a device which altered the polarity of the current continuously; and a second where current was constantly interrupted. The incandescent lamp was still very new, and now that Edison was considering its introduction, he wanted to know more about its stability under different circumstances.

Among other duties, Wilson S. Howell and I took care of these tests. In 1881, 'Rene' Thury also assisted. He became an expert and inventor in his fatherland, Switzerland, when he returned home. He was well-known as a pioneer worker in long distance transmission of electrical energy with direct current and high tension.

At that time, Hammer was already at the lamp factory. Howell had finished the task of laying miles of underground conductors to be used in the coming second display of Edison's system, as well as in extended tests.

Edison was gratified to note that the lamp tests showed



'Rene' Thury in 1933 in garden at Geneva, Switzerland.

improved results as time went on, and that the manufacturing of lamps was also progressing. We had a celebration on Tuesday, January 4, 1881, when the last of a special test of 'B' bamboo lamps had expired. It had been in service 2,450 hours, and was one of the first eight-candle lamps made at the laboratory in May, 1880, before the lamp works were in operation.

I might mention that this celebration has been misrepresented in some newspaper articles. We persuaded Upton and Batchelor to march with Edison through the laboratory and machine house, while we all followed carrying the lamp in a little casket, imbedded in cotton batting.

Of course, no lamps were being sold as yet. The only ones to leave Menlo Park were those sent overland to the S. S. *Columbia*, arriving in Portland, Oregon, July 26. The steamer, as will be remembered, was fitted out with paper horseshoe lamps when she left New York, May 2, 1880.

Those first bamboo lamps were not made at the lamp factory, but at the laboratory, and were shipped in barrels overland to the Coast.

'Send us a barrel of lamps,' was a common order received in the early days.

In connection with the second exhibit, Charles L. Clarke was requested by Edison to study the program and methods of making a complete and thoroughly detailed test of the commercial efficiency of the Edison system. As Clarke was a clever mechanical engineer, Edison was able to confide in him in this respect. It mainly involved, not only academic knowledge of steam engineering, but also the ability to organize such a test and carry it out to the satisfaction of Edison and outside engineers.

The situation at that early period was far different from today. Clarke's economy test was probably the pioneer epitome on that subject on a large scale in the history of electric incandescent lighting. As a historical document it

will be added later to these reminiscences of Menlo Park.

In an earlier chapter, I persuaded Clarke to contribute personal reminiscences of Menlo Park. I wish to say here that, in addition to his mathematical and engineering attainments, he was likewise a superdraftsman. His work was like a steel engraving. No one at Menlo Park could approach him in such skill, and he designed not only the working drawings of Edison's first Jumbo steam dynamo, but all subsequent ones.(1)

Edison's ideas early in 1880 about a central station with many belt-driven generators were by now discarded, for he realized that in the future only direct-driven generators from prime motors would be employed without belting. He knew that large generators would be more efficient in many ways than many small units.

So it happened at that early period, when there existed but a few crude little current generators of different makes for arc lighting—when little was known and contesting views existed about the theories of generators—that Edison, with courageous confidence and knowledge of what he was doing, determined to build a large direct-driven generator for experimental study.

It was considered a daring experiment that would incur a great deal of expense. He wanted a special high-speed steam engine of more than 100 horsepower, fitted on a common cast iron base with a large generator. He decided to confer with Charles T. Porter, designer of a high-speed steam engine, the Porter-Allen, which was being built at the Southwark Foundry and Machine Works in Philadelphia, Pennsylvania.

I remember that Porter often came to the laboratory and conferences took place between Edison, Porter, Clarke and Upton, resulting in an order for an engine to run about 600 r. p. m. As I have already mentioned, Clarke drafted the whole combination, and Kruesi was given shop drawings to start building the largest generator ever made up to that time.

Of course, the 'Jumbo' dynamo was designed fundamentally on the same principles as the 'A' type, which has been discussed in a former article.

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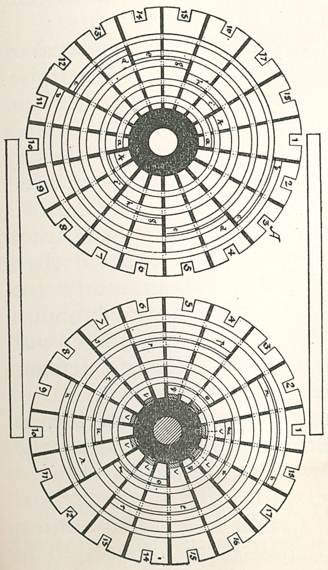
(1) Even today (1938) as I write these lines this venerable octogenarian still pens calligraphic letters.

According to Clarke, its dimensions were as follows:

'The field magnet had six cores, 42½ inches long and 7½ inches in diameter, each wound with 1,860 turns, in six layers, of No. 12 B.W.G. insulated copper wire, and having a resistance of 3,825 ohms. The laminated armature core of thin iron discs was mounted on a 4½-inch shaft, had an internal diameter of 10 inches, an external diameter of 19.46 inches, and a length of 28 inches. The field poles were 28 inches long and 20½ inches inside diameter.

'The resistance of the armature was reduced to the lowest practicable amount by adopting the bar-method of winding, with 138 copper bars on the face of the armature and copper radial and circular end pieces for connecting the bars into a closed-coil winding. The commutator had 69 sections. The armature bars and connecting end pieces were insulated from one another by mica, cemented together into blocks or strips, which completely filled the intervening spaces.'

The patent drawing on this page will assist the reader in forming an idea how the bars and end pieces were connected, so as to form a complete circuit (as done generally when armatures are wound with wire).



Drawings from Edison's patent application covering 'Magneto or Dynamo Electric Machine.' Patent No. 242,898.

My job was to test the resistance and insulation of the field magnet, as well as the armature of this first Jumbo.

I remember that my measurements of the armature resistance were not quite so satisfactory as I thought they should be. First I used our

regular Wheatstone bridge box and found that it was like trying to weigh a grain on a commercial scale.

I had Kruesi make a special bridge according to my drawings, a sliding Wheatstone bridge, better suited for measuring very low resistances. In that kind of bridge the comparing units are in themselves of very low resistance. When measuring electrical resistances, it is always best to compare them with similar known resistances, just as you would weigh a pound on a grocer's counter scale and not on one used to weigh objects of 100 pounds, or more.

When the armature resistance was measured, it indicated more than it should. When we ran this gigantic dynamo later, we found that the connection places where the bars were screwed on the radial end pieces, and so on, were unduly heated.

As already mentioned, Edison made this costly experiment to study and learn what defects would appear during the trial tests. He also found that it would not be safe to run the engine at 600 r. p. m.

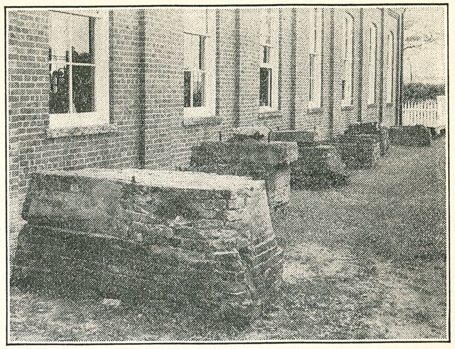
I remember the day when we started the engine. Hood was our steam engineer. As he slowly opened the valve, the engine began to speed up and produced vibrations felt in the entire building.

As it began to pass 500 revolutions, the vibrations became so tremendous that everything began to shake. The noise was deafening. Some of us thought it would be better for our health to get out of the building. We had hardly passed the door when we heard the engine slowing down. Clarke, who measured the speed of the engine, found that it ran over 700 r. p. m., too high a velocity.

Charles Porter was present and, of course, there were plenty of arguments and discussions. Edison realized then that the limit of practical safety would be about 300 to 400 r. p. m. with that kind of engine and direct-connected dynamo. Again, Edison found that the Porter-Allen governor was somewhat too sensitive, even fidgety, but Porter's defense of it silenced Edison's premises for the time being.

The machine was next tried at a lower speed and it was during that test that the defective connections, or rather the manner in which those connections had been made, induced Edison to order certain changes before making further trials.

When this decision was made, Clarke was still rooming with the Thornalls, who occupied half of the house where



In foreground is salvaged foundation from Menlo Park Machine Shop. To this the Porter-Allen steam engine was anchored. Now in rear of restored machine shop, Greenfield Village.

Dean lived next to the Jordan boarding house. (It may be mentioned that Upton bought from Thornall the house into which he moved when he was married. Mr. Thornall then bought the double house next to Mrs. Jordan's, and Dean was his tenant.)

First tests of the large Edison dynamo were made in January, 1881. The whole unit, dynamo and steam engine on one base, was stationed in front of the Brown steam engine that supplied the power to the eleven dynamos, generating the current for this second and final exhibition.(2)

I tested the commutator of the large dynamo, which Dean had made. It had a short circuit.

After Clarke left Menlo Park on February 7, 1881, to take up his duties as chief engineer of the Edison Electric Light Company in New York City, he was always kept informed as to how matters stood with the steam dynamo.

Porter was present at times and contributed suggestions. During these days in early 1881, Edison was often absent, as matters were pressing him in New York. Sometimes it happened that when he came to Menlo Park he would give orders to have the big machine ready for a test. On February 10, Edison was in New York all day and returned late to Menlo Park, going directly home. In the morning we were informed that he was not feeling well and would not come to the laboratory. Next day, some newspapers reported that Edison was ill and had given up his work on electric light. This was, however, instantaneously refuted by G. P. Lowrey, who always kept his eyes open for such false statements.

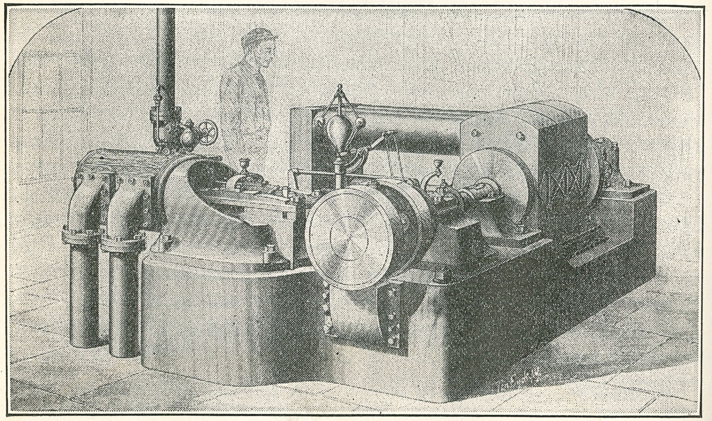
(2) When Henry Ford went to Menlo Park in 1928 and 1929, he found, among other things, the concrete and brick foundation upon which the Edison-Porter unit was bolted. This foundation, still intact, may be seen today outside the Edison Machine Shop in the restored Menlo Park, in Dearborn.

I went to Princeton College to standardize a resistance which I needed for my sliding Wheatstone bridge. Coming back to Menlo Park on the 9:15 evening train, I found the laboratory full of visitors, mostly hotel and post office people.

On the next day, February 12, Edison came to the laboratory and asked me to make tests again of the large armature. He stood by, watching the results. The measurements that I obtained were far from flattering, for the armature of this large dynamo gave a resistance of about 0.18 ohms, which, considering the large cross section of the copper bars, was poor. Even today this would seem hard to believe, but my diary of February 12, 1881, confirms my figure.

Our regular 'A' 60 lamp-type generators that were supplying the current for this second exhibition each had only an armature resistance of about 0.14 ohms. Edison had me repeat the test three times. We saw that the contacts in the Wheatstone bridge and the leads that made contact at the commutator were in proper shape. We worked on the armature until about 2:30 a. m., finding that the electrical contacts at the bar ends, radial pieces and circular connection pieces were not good.

The next day being Sunday, I remained in bed until about 11 o'clock when I was awakened by a thumping on my door and I heard Mrs. Jordan telling me that Edison had just passed



Experimental 'Steam Dynamo.' Menlo Park, 1881.

the house, with the message that if I was there I should come to the laboratory.

When I arrived, Edison told me that he wanted to try soldering the joint connections with the electric arc. If I remember correctly, we took the current from a sixty-light dynamo that was belted to our Hampson steam engine which usually was sufficient for driving the machinery in our shop, and which had been placed in position only a short time before. It stood in the machine shop just as it does now in the restored one at Dearborn.(3)

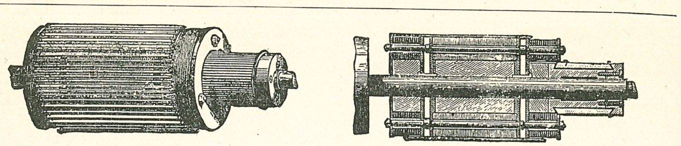
Our electric soldering experiment was not a success. Edison soon found that he could not fuse the contact extremities properly and that first he would have to make a special study of the process before trying it practically. Professor Elihu Thomson had not yet invented his resistance welder; it came five years later. After fusing the ends of some of the bars and their neighbor contact pieces, he gave orders to have the whole machine taken apart. Edison stayed at the machine shop all day, conferring with Upton, Kruesi, Logan and Dean.

I remember that Edison was not satisfied with the manner in which the copper bars of the armature were connected in order to form the closed-coil winding. I refer to the radial copper pieces and the circular end ones and the little contact surface they presented. The high armature resistance that I received in testing and as above noted came from the insufficient conducting surface at their connections.

Edison talked about concentric insulated copper band rings to take the place of the radial end connecting rings. He pictured these band rings having projecting parts or lugs to which the bars were to be attached. The result was, if I am not mistaken, that he gave orders to rush another idea: use of insulated copper discs with lugs at each end of the armature for connecting up the copper bars in regular drum armature fashion.

He tried this disc idea first on the small sixty-lamp model of his generator, where it worked well and served as a system of connecting up the future large generators, the Edison 'Jumbo' generators which were made in New York City. The little sixty-lamp generator with the disc winding was shown at the Paris Exposition in 1881, and in a few months

(3) Later it was shipped to the Edison headquarters at 65 Fifth Avenue, New York City, for lighting purposes.



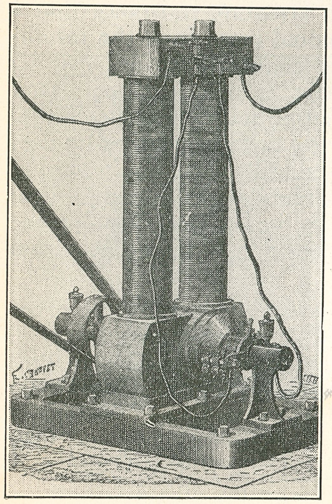
Left—Armature of the sixty-lamp disc dynamo. Right—Cross section of the dynamo.

an Edison steam dynamo which had been built at the Edison Machine Works in New York City was also sent to Paris.

Two old letters from Clarke to Logan seem to substantiate the correctness of my recollections on this subject. As I have said, it was a rush job and the men in the machine shop worked day and part of the night to finish it. An idea of this mode of disc connection can be obtained from Edison's patent drawing No. 263,146.

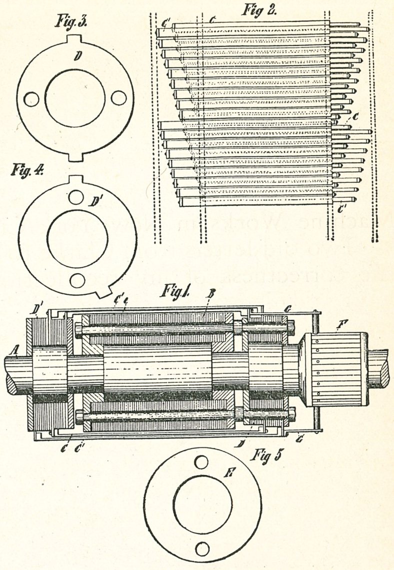
In the evening Edison went home for supper, later returning to the laboratory, where he remained until 1 a. m. As Kruesi was to leave in the morning to start the Edison Electric Underground Tube Works in New York City, Logan was appointed foreman of the machine shop. That was on February 14, 1881.

It may be mentioned that Dean, one of the oldest men in Edison's employ, already had been appointed to aid in starting the large machine works in New York City, which work was soon to commence. It was Dean, one of Edison's principal mechanics, that Kruesi had entrusted to build the experimental large dynamo's armature, and when Kruesi left for New York City, Dean still remained on this particular job, although Logan became the foreman. There existed no rivalry, for Dean knew he had a big job ahead as soon as Edison had found a site in New York City for his machine works.



Complete sixty-lamp disc dynamo made at Menlo Park in 1881 and sent to Paris Exhibition.

Although Edison left for



Drawings from Edison's application for patent on the Jumbo dynamo. Patent applied for November 22, 1881; granted August 22, 1882. No. 263,146.

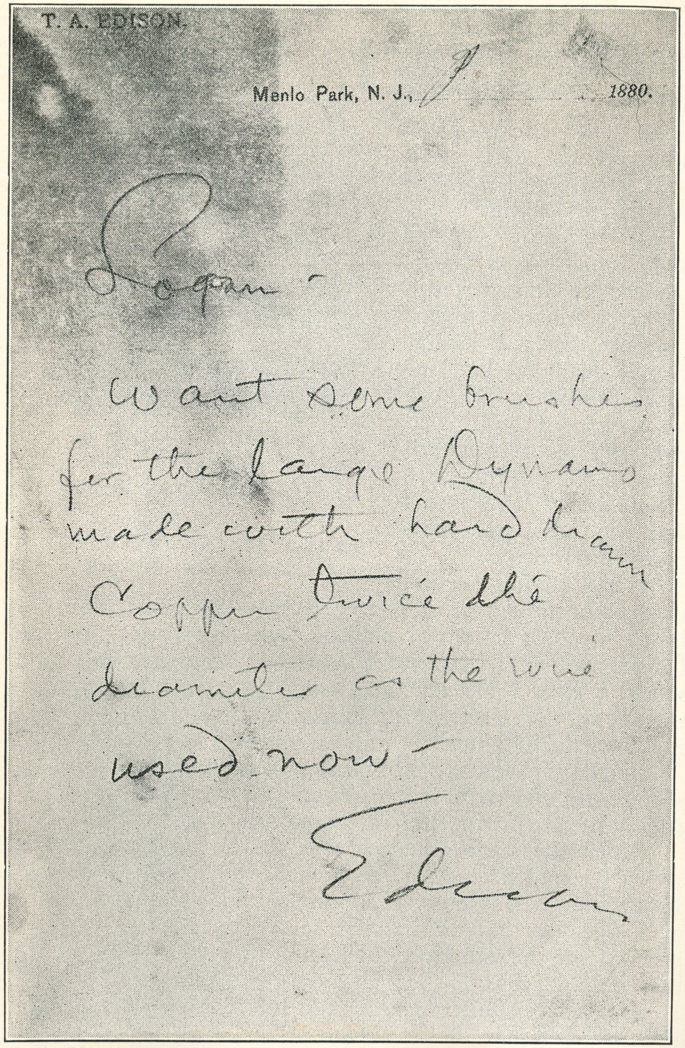
New York early the next morning, the large dynamo armature was soon taken apart and work was commenced to improve the contact joints in every possible manner that would lead to less internal resistance of the armature. I was also engaged from time to time in measuring the resistance of the joints and was often past midnight on the job.

I had found a good method of measuring the resistance of the joint connections by the drop of potential method, which was far more satisfactory and surer than the Wheatstone bridge for this kind of work. This I already had employed in determining the shunts of the electrolytic Edison meter, explained already in an earlier chapter.

Clarke, in New York, was kept informed on how matters stood with the large armature, and he often sent letters with orders to do this or that in connection with it.

When the large armature was finished and repaired, and when I tested its internal resistance, the results surprised us. Its resistance was now 0.015 ohms, quite different from the 0.18 ohms it had when first tested on February 12. We worked on the armature all night until six in the morning and then I went to bed and slept till four o'clock in the afternoon. As Edison was still in New York, we telegraphed the news to him and he answered that he would come to Menlo Park on Sunday, February 20.

Edison and Clarke arrived in the afternoon and I was asked to connect the field magnets of the large dynamo.



T. A. EDISON.

Menlo Park, N. J., 1880.

Logan —

Want some brushes for the large Dynamo made with hand drawn Copper twice the diameter as the wire used now —

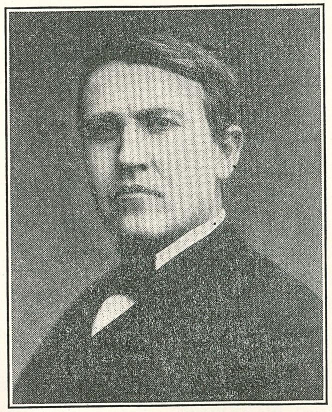
Edison

During tests, Edison had Logan, chief mechanic, make differently-sized commutator brushes. One such order appears above. Now in restored machine shop at Dearborn.

Hood and some of the 'boys' were on hand and when the steam was up we ran the combined unit until about midnight. The tests that we made with the unit were more of a mechanical nature, for Dean and others had succeeded in reducing the vibrations to such a degree that we all felt assured.

Edison, Clarke and Hood also made trials with the Porter steam engine governor on the engine in order to get a better idea of its sensitiveness, and so time passed without making a test with a load on the big armature.

'We shall be here again on Thursday and will give the armature a good trial, for Dean is going to fix the brushes and some other things,' was Edison's assurance.



EDISON in 1883.

LXXXIX. The Jumbo Dynamo—

(PART TWO)

ON THURSDAY, FEBRUARY 24, Edison and Clarke arrived at Menlo Park, followed shortly by Upton and Batchelor from the lamp works. Talk centered on the large dynamo. As usual, we gave an exhibition in the evening, lighting up Menlo Park with the eleven 'A' generators run by the Brown steam engine. We stopped about 8:30 p. m. and prepared to run the Porter-Allen Edison unit.

Howell reported that the outside network was in good working condition. He remained with us to take part in the test. Clarke, with his speedometer in his hand, stood by, as well as Edison and the others, watching Hood let a little steam into the engine to warm it.

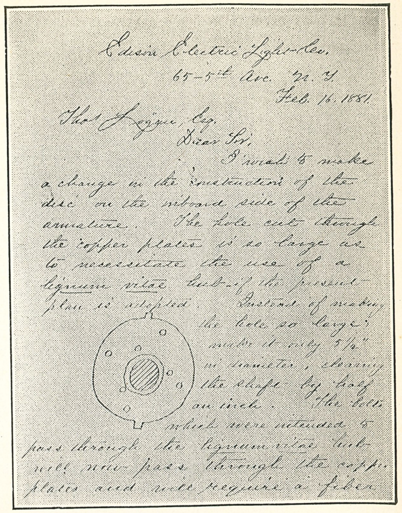
Howell assisted me in connecting the large dynamo to the outside network, the terminals of which came into the dynamo room where the eleven generators were.

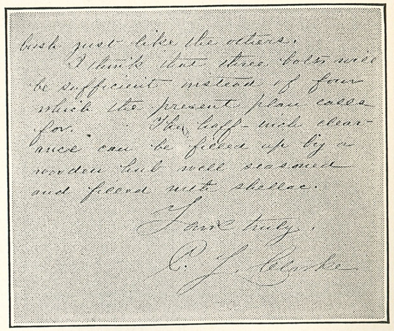
After Hood had the Porter steam engine well warmed, Edison told him to let it run slowly and give it more steam gradually. Edison then requested us to connect first only a part of the network to the large dynamo, and told me to go to the field magnet regulating resistance box and regulate it as the engine acquired speed.

The eleven 'A' dynamos were regulated from my testing table in the laboratory, for Edison made it a point to show visitors how remote control was one of the features of his system. There at the testing table the electromotive force or tension was also measured. However, in the experiments with the big steam dynamo, we had made a special temporary resistance box for the regulation of its field, while the tension at its armature was measured as usual at the laboratory testing table.

When everything seemed in good order Edison told Howell to 'plug her in.' We had large plug switches in those days for completing a circuit; that is, connect the section of the network. I gradually cut out the regulating

Letter from Charles L. Clarke to Thomas Logan. Now in restored machine shop, Dearborn.


Edison Electric Light Co.
65-5th Ave. N. Y.
Feb. 16. 1881.
Thos. Logan, Esq.
Dear Sir,
I want to make a change in the construction of the disc on the inboard side of the armature. The hole cut through the copper plates is so large as to necessitate the use of a lignum vitae hub if the present plan is adopted. Instead of making the hole so large, make it only 5 1/4" in diameter, clearing the shaft by half an inch. The bolts which were intended to pass through the lignum vitae hub will now pass through the copper plates and will require a fiber


bush just like the others.
I think that three bolts will be sufficient instead of four which the present plan calls for. The diff. in clearance can be filled up by a wooden hub well seasoned and filled with shellac.
Yours truly,
C. L. Clarke

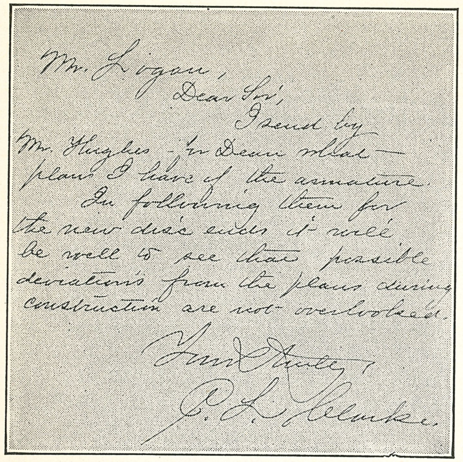
resistance and we could see that the lamps in the machine shop, the laboratory and the east side of Menlo Park began to get brighter and brighter.

It was a tense moment for all. Edison's glance anxiously darted from one place to another. When everything seemed to be going well, his countenance slowly relaxed into a smile.

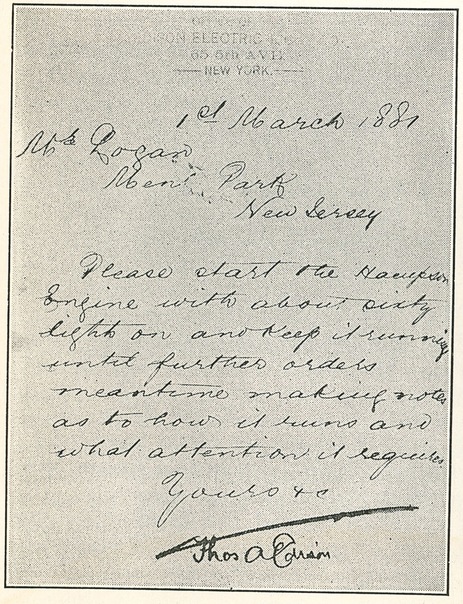
We ran about one hour with this load, and then Edison told Howell to plug in the whole network. At last the crucial test for the mammoth Edison dynamo had come. All the lights of Menlo Park were lighted—about 426 lamps being connected. My Thomson reflecting galvanometer in the laboratory registered about 100 volts when the Porter-Allen steam engine ran at 535 r. p. m. Of course we could have used a few volts higher tension, but that did not bother Edison who said, 'We will get it when we build another one.'

The machine kept on working and ran until midnight, when Edison ordered Hood to stop the engine. Edison was pleased, and his face beamed as he laconically said 'Fine!'

An animated conversation took place between Edison, Upton, Clarke and Batchelor. The machine's speed was


Mr. Logan,
Dear Sir,
I send by
Mr. Hughes - in Dean what -
plans I have of the armature.
In following them for
the new disc ends it will
be well to see that possible
deviations from the plans during
construction are not overlooked.
Yours truly,
C. L. Clarke

Another letter from Clarke to Logan. Now in restored machine shop at Dearborn.


OFFICE OF ... EDISON ELECTRIC L... 65 5th AVE. NEW YORK.
1st March 1881
Mr Logan
Menlo Park
New Jersey
Please start the Hampson
Engine with about sixty
light on and keep it running
until further orders
meantime making notes
as to how it runs and
what attention it requires.
Yours &c
Thos A Edison

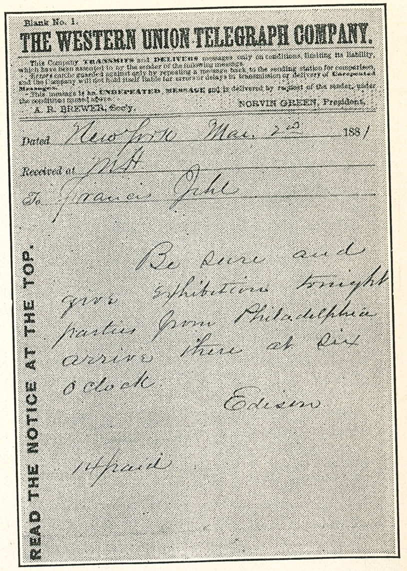
Instructions to Logan regarding Hampson engine. Now in restored machine shop.

discussed, for 500 r. p. m. was too high.

After about half an hour, someone said: 'Let's go down to Davis' Lighthouse and celebrate with a drink to the success of the giant.' The suggestion was immediately seconded and not until then did we notice the crowd that had come to the shop. A large group of the 'boys' from Menlo Park, and some from the lamp works, had assembled to witness the test of the large machine. All were in good humor and as we marched across the field toward Davis' Inn we sang, no doubt disturbing the slumbers of some residents.

The 'Lighthouse' was closed when we arrived, but the 'boys' soon managed to get 'old man Davis' to open up. He wanted to know if we were a be-

Telegram from Edison to Jehl regarding exhibition at Menlo Park.


Blank No. 1.
THE WESTERN UNION TELEGRAPH COMPANY.
NORVIN GREEN, President.
A. R. BREWER, Sec'y.
Dated New York Mar 2d 1881
Received at MP
To Francis Jehl
Be sure and
give exhibition tonight
parties from Philadelphia
arrive there at six
o'clock
Edison
14 paid
READ THE NOTICE AT THE TOP.

lated Washington's birthday party winding up the celebration.

'No,' we told him, 'we are going to celebrate the success of Edison's big dynamo.'

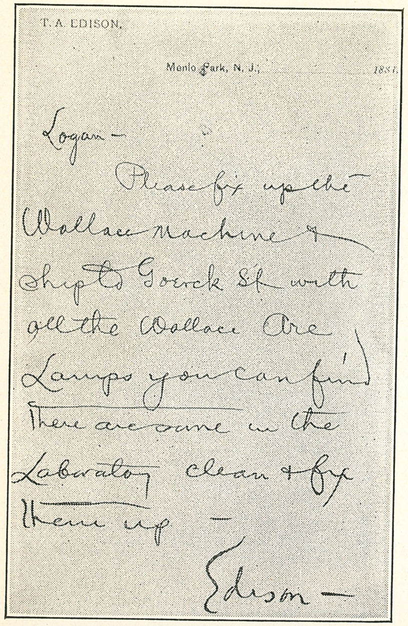
Soon the clinking of glasses and toasts to Edison were heard. The hilarity and bustle in the saloon no doubt awakened Mackenzie who boarded there, for he soon willingly joined us. It was late in the morning when we separated and went home. As my diary records, there were many headaches the next day—which was February 25, 1881.

Edison and Clarke left for New York, and two days later the former returned with Johnson. The large generator was started again, lighting all Menlo Park. Johnson was leaving for England on the following Tuesday, so Edison explained everything to him. His mission abroad was to start an English Edison Electric Light Company, for which capacity he was well fitted, being gifted with the power of persuasion. He was what we call today a super high-pressure promoter.(1)

After the big generator was stopped Johnson seemed exultant, and in a moment of enthusiasm he invited the 'boys' to the 'Lighthouse.' There, again, round after round was proposed to Edison and his success, followed by more headaches next day.

In many ways Johnson was liberal, and then again he was aggressive. What he did was done mostly in a showman's way. As I have said, he was most persuasive, and could almost convince you that black was white. In those pioneer

(1) See pp. 58 and 167, Volume I, Reminiscences of Menlo Park.


T. A. EDISON.

Menlo Park, N. J., 188

Logan—

Please fix up the Wallace machine & ship to Goerck St with all the Wallace Arc Lamps you can find. There are some in the Laboratory clean & fix them up —

Edison —

Message from Edison to Logan asking for Wallace arc lamps and generator. Now in restored machine shop at Dearborn.

days when men had to push and fight to get ahead, he did his work well, and in all loyalty to Edison. In England one newspaper said, 'There is but one Edison, and Johnson is his prophet.' Others called him 'breezy Johnson.' He deserves credit for the work he did in England as Edison's representative.

Coming back to America later, he succeeded in talking himself into the Edison Electric Light Company as its president during the early turbulent days of lawsuits. He also tried manufacturing with others, and succeeded in amassing some wealth. With a lavish hand he established an estate in Connecticut, where he kept fine horses. At last, when conditions arose beyond the control of those who did not possess the necessary vision or foresight, things changed.

According to my diary it was on March 2, 1881, that Edison's new secretary, Samuel Insull, made his first visit to Menlo Park. He came from England where he had been employed by Colonel Gouraud, Edison's English agent. Johnson was located there most of the time while in England, and young Insull learned of doing business and promoting companies from him.

Insull was not a Menlo Parker, for when he landed in America in 1881, Edison was living in New York City, and most of the others had left, also. The great days of experiments and achievements had passed, and Menlo Park was beginning to fade slowly into that decadence or slumber

which lasted until it was restored to its ancient glory in Dearborn.

Francis Jehl and Wilson S. Howell photographed in Greenfield Village tintype studio in 1937.

Insull was one of the second edition of Edison pioneers who commenced their service in New York City. He wrote at that time to England and said: 'Menlo Park is practically abandoned, all experiments are finished.'

Like others, he came now and then to Menlo Park to hunt up some letter or paper that was filed in the office. Many men came out to Menlo Park regularly. One was Mr. Auerbach who came to our bookkeeper, Carman, in order to make up his account of the laboratory's expenditures to be presented to the men who advanced the money to Edison for his electric light experiments.(2)

Berggren, Carman's assistant, will no doubt remember Auerbach. Berggren came to Menlo Park on April 11, 1880. Later he was transferred to assist Charles E. Rocap, bookkeeper at the Edison Goerck Street Machine Works in New York City. In 1886 he followed the machine shop to Schenectady, New York, where he continued to assist Rocap. Rocap left later, and Berggren became head accountant for the General Electric Company. In 1910 Edison asked him to come to West Orange, New Jersey, as secretary and treasurer of the phonograph works. He remained there until 1916, and has always continued to be a loyal Edison man.

The next time I saw 'Sammy,' as the boys soon called Insull, was at the 65 Fifth Avenue office where he worked. He was talking to Jim Russell, an operator of a private detective concern, who came often to Menlo Park. Once he appeared at the laboratory somewhat bedraggled, and told us that while on duty a few days before, he had become involved in a mess and was so badly beaten up that the doctor covered his entire back with porous plaster. He took

(2) Mr. Auerbach was of the firm of Porter, Lowrey, Loren and Stone. When the firm was dissolved he associated himself with Lowrey.

off his shirt to verify it, and was promptly nicknamed 'Porous Plaster Jim.'

According to my diary, Edison visited Menlo Park again on March 9, followed by Insull. We started the large dynamo and worked on it all night, as the bearings became hot. Porter was also present and on his request we took the large machine apart the next day to fix the bearings, as will be noted in the letter on page 887.

My diary records that the 'boys' had a little sport with Insull, poking fun at his English mannerisms and hoaxing him in regard to American customs, depicted so well by Charles Dickens. He took it all in, in his peculiar way, for he had not yet warmed the seat of his office chair in New York. He was a young fellow (about my age) and lived at the Edison headquarters in New York where, on an upper floor, a room was fitted with beds for the workers.

Clarke, as I have already mentioned, had left Menlo Park on February 7, and he also roomed at the 65 Fifth Avenue headquarters, for he once wrote me, 'For several months in 1881 Sam Insull was my chum and roommate there.' Some of the other 'boys' also slept in this Edison improvised dormitory, when they moved from Menlo Park to New York.

Wilson Howell, my old Menlo Park laboratory friend, who is still living in California, wrote me last year(3) that he met Samuel Insull soon after Insull landed in New York.

Yes, we 'boys' of that period knew him, but Howell gives a touching reminiscence of that time. He says, 'Sam was about twenty-one years of age. We lived at 65 Fifth Avenue. Mr. Edison had allowed some of us to occupy a room on the top floor of the building. We had beds there. I remember Samuel Insull the first Saturday he was in the United States. All of us had homes out of the city where we usually went for Sundays. Once Insull stood by a window, homesick for his home in England, quite a forlorn boy; contemplating a Sunday in that strange city. While we chatted about our trips to our homes he was heard to say "Home! home! You chaps all have homes to go to—mine is far away." I felt sorry for the boy so I invited him to come with me to my home in New Brunswick, which he was glad to do.'

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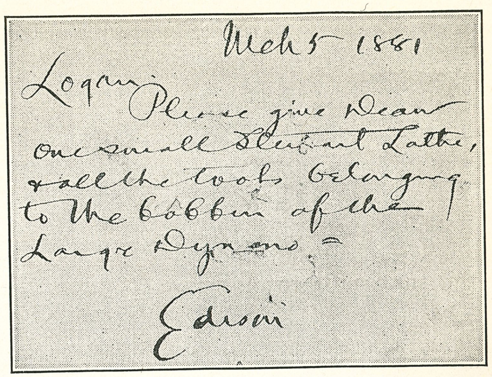
(3) 1935.


Mch 5 1881
Logan
Please give Dean
one small Student Lathe,
& all the tools belonging
to the bobbin of the
Large Dynamo =
Edison

Note from Edison to Logan, foreman of Menlo Park Machine Shop in 1881. Now in restored shop at Dearborn.

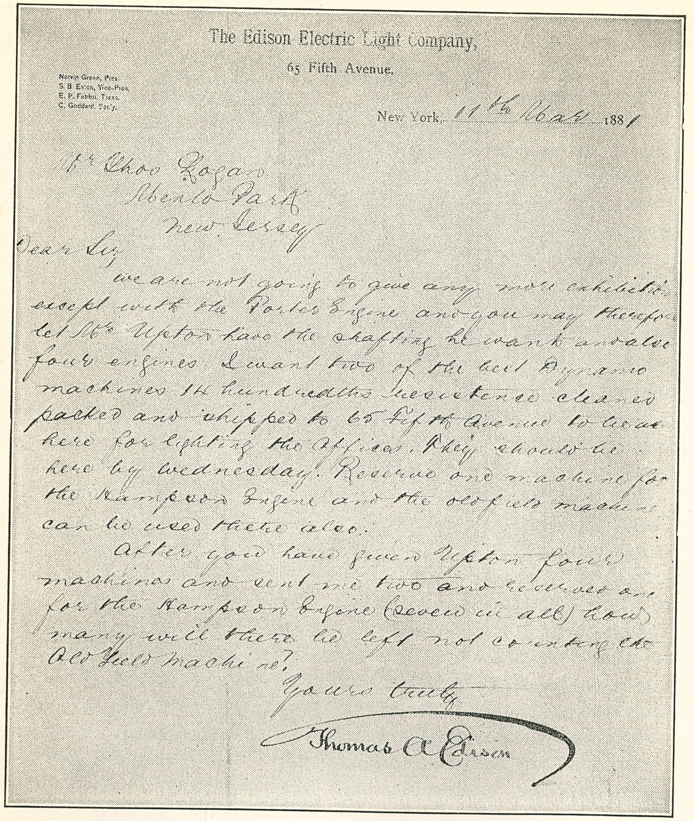
Of course, that was during a period when he had been but a short time in America, but he readily managed to acclimate himself, and soon he became acquainted with business men who frequently came to the Edison headquarters. He had to take care of all of Edison's correspondence and other office work. He had a knowledge of shorthand and he wrote the letters in longhand, as the typewriter was not commonly used.

Unfortunately, Insull did not possess that congenial disposition that marked the characters of the Menlo Park boys and, consequently, he had few friends among them. This did not deter him or the 'boys,' for they were independent from one another, and any stories to the contrary must be taken with a pinch of salt. One thing was certain: Insull came into a position at a period fraught with exceptional advantages in a business sense, and no better training school for a young man could have been found. He learned, gradually gaining experience from the men who visited 65 Fifth Avenue, business men, bankers, company promoters, and so on.

To keep one's eyes open and perhaps work into a key position or front man even at a small salary might turn out well in the future, and many young men took advantage of their opportunities.

I will now return to March 10, 1881, on which day we took the big Edison dynamo apart again. The work was finished next day, and when Edison saw that the big unit ran satisfactorily, he gave orders that from then on all light exhibitions were to be given only with the Porter engine-dynamo.

There was another reason for this order. Upton, at the lamp factory, was in need of shafting and dynamos. An



The Edison Electric Light Company,

65 Fifth Avenue,

Norvin Green, Pres.
S. B. Eaton, Vice-Pres.
E. P. Fabbri, Treas.
C. Goddard, Sec'y.

New York, 11th Mar 1881

Mr Chas Logan
Menlo Park
New Jersey

Dear Sir

We are not going to give any more exhibitions except with the Porter Engine and you may therefore let Mr Upton have the shafting he wants and also four engines. I want two of the best Dynamo machines 14 hundredths resistance cleaned packed and shipped to 65 Fifth Avenue to use here for lighting the offices. They should be here by Wednesday. Reserve one machine for the Hampson Engine and the old field machine can be used there also.

After you have given Upton four machines and sent me two and reserved one for the Hampson Engine (seven in all) how many will there be left not counting the Old Field machine?

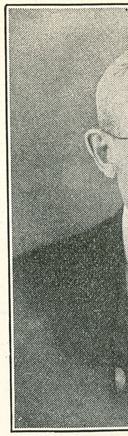
Yours truly

Thomas A Edison

Orders from Edison to use Porter-Allen engine and large dynamo in Menlo Park exhibitions. Letter inscribed by Samuel Insull and signed by Edison.

engine and boiler had been purchased which would generate the necessary current and power, and relieve our powerhouse at the laboratory machine shop. At the same time Edison required a couple of dynamos for the Edison headquarters in New York City. Thus, March, 1881, was the time when the electric power room behind the engine room, with its eleven 'A' type Edison dynamos, was dismantled.

Here I may mention that Vail, dynamo tender at the time,

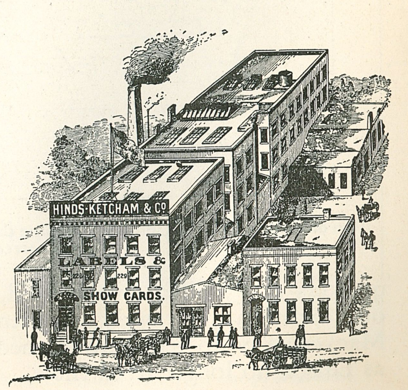


Charles T. Hughes. Employed at Menlo Park early in 1880 as purchasing agent. In 1881-2 had charge of demonstration of second electric railroad. Later held an important position with the General Electric Company.

was sent to New York City and at the Edison headquarters mounted the two dynamos in the basement. An Otto gas engine supplied power to run them, and later our little Hampson steam engine was substituted because the speed of the gas engine fluctuated and made the light unsteady.

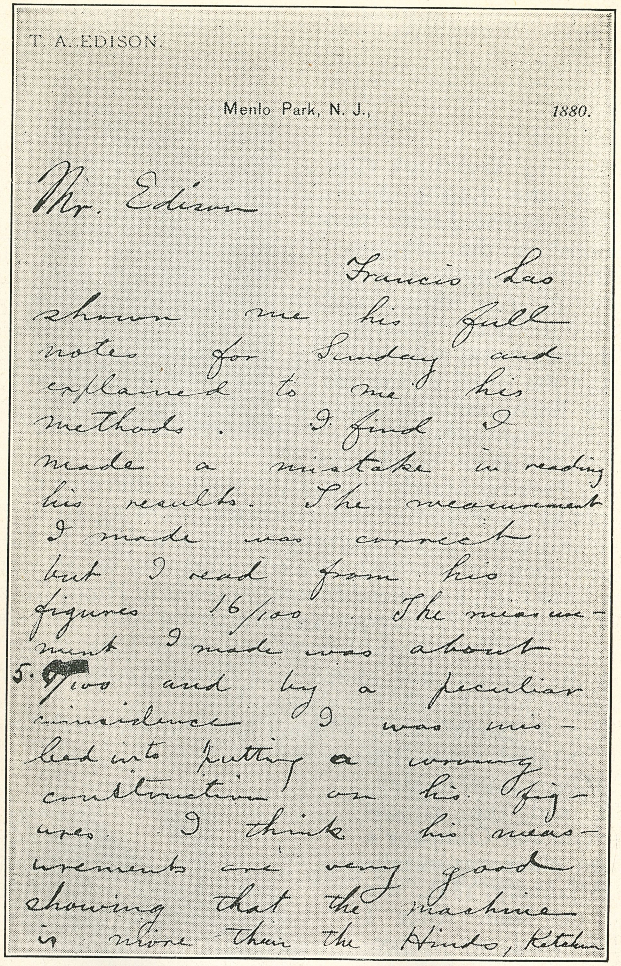
Edison came back to Menlo Park on March 15, and we made a curve of the field magnet of the Porter-Edison generator, working all night to make this test. In the morning I took a walk with Hughes to Metuchen and returned. Shortly afterward we all went to New York City, I to attend to some business at Hinds-Ketcham and Company, lithographers and printers of colored labels and show cards. From there I went uptown to look at the new shop that Edison had rented—104 Goerck Street—formerly owned by John Roach, the ship builder.

The S. S. *Columbia*, which I have mentioned before(4), was installed with the first Edison plant in May, 1880, and the Hinds-Ketcham and Company's Edison plant was installed in January, 1881, the first on land. After I had finished my inspection there, I went to head-



Hinds-Ketcham & Company's factory at 449 Water Street, New York City. One of Edison's first commercial installations; and the first on land.

(4) Chapter LXIII.



T. A. EDISON.

Menlo Park, N. J., 1880.

Mr. Edison

Francis has shown me his full notes for Sunday and explained to me his methods. I find I made a mistake in reading his results. The measurement I made was correct but I read from his figures 16/100. The measurement I made was about 5.[illegible]/100 and by a peculiar coincidence I was misled into putting a wrong construction on his figures. I think his measurements are very good showing that the machine is more than the Hinds, Ketcham

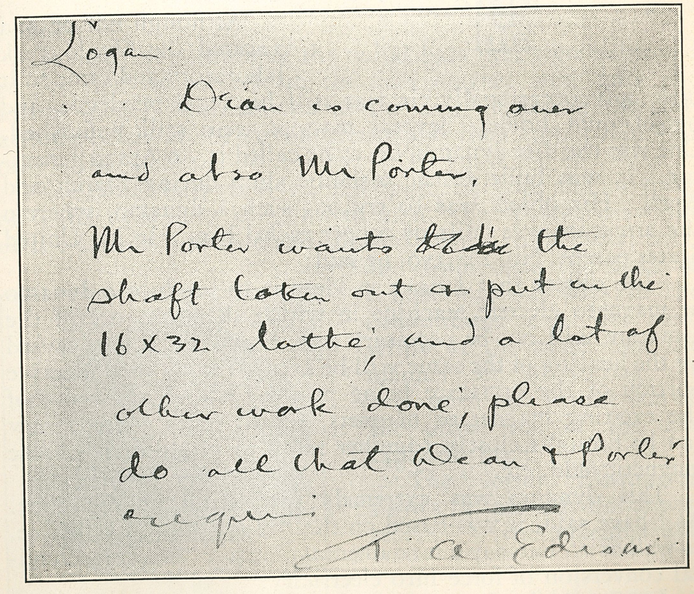
Part of letter written by Upton explaining that Jehl's method of testing dynamos was correct.

quarters at 65 Fifth Avenue and, among others, met Mott, our draftsman, formerly at Menlo Park; also, good old Mackenzie who had now turned his back on Menlo Park as Edison no longer lived there.

After supper that night we went to the Park Theater and saw 'Fresh the American.' We took the midnight train back to Menlo Park.

On May 23, 1881, Edison came down and had me connect the big dynamo. We ran it many hours until early morning when the armature got cross, thus ending what we afterward called the first experimental Edison Jumbo. We learned much about it, Edison as well as the others. When he began building twenty-three of them at his Goerck Street Machine Works, the defects in the armature construction of the Menlo Park Jumbo were avoided; and from the experience gained, the new models served to create the historical precedence of commercial central station delivery of light, heat and power for the future.

Edison was convinced that the new models of armature construction and field magnet system were not yet ideal, and that many changes were to come, but they had to be started and set going commercially. He knew that in the future others would improve the construction. He had



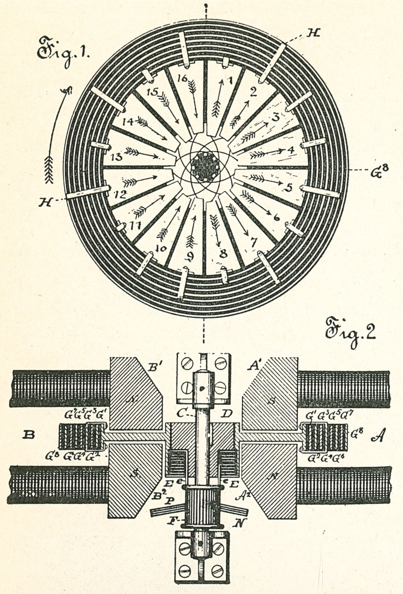
Logan.

Dean is coming over and also Mr Porter.

Mr Porter wants the shaft taken out & put in the 16 x 32 lathe, and a lot of other work done; please do all that Dean & Porter require

T A Edison

Note from Edison to Logan. Now in restored machine shop, Dearborn.



Drawings Patent No. 263,150. Applied for June 3, 1881. Granted August 22, 1882.

shown with his first sixty-lamp dynamo of 1879 that an efficiency of 90 percent could be attained and that the commercial conversion of mechanical power into electricity was assured. Thus he had set pioneer standards for the rush that was to follow; had opened vast fields looking toward the practical and commercial use of electricity.

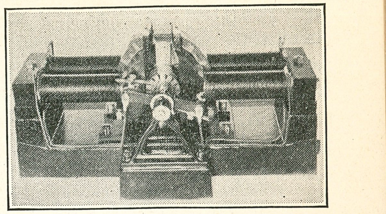
Although Edison had vacated the Menlo Park laboratory and came to it now only occasionally, it was still his legal residence, and out-of-town home. Several matters were still unfinished. One was the disc dynamo, or, as he called it, an Arago generator. It was built at the machine shop during March and April. His object was to try out such a dynamo, wherein the armature was built of copper radial bars. In his United States patent, No. 263,150, he said:

'The object that I have in view is to produce a dynamo or magneto electric machine in which the iron core of the armature will not be necessary and the loss of power caused by the heating of the same will be avoided, only the inductive portion of the armature being passed between the poles of the exciting magnet or magnets, which poles consequently can be brought closely together so as to produce an intense magnetic field, etc. . . .'

This dynamo was extremely interesting at the time. As I have said, it was based on the Arago rotation principle, as well as on Faraday's fundamental discovery of the mechanical conversion of force into electricity.

In 1824 Arago found that when a copper disc was rotated

Edison dynamo with radial copper bars, 1881. Now in restored laboratory at Dearborn.



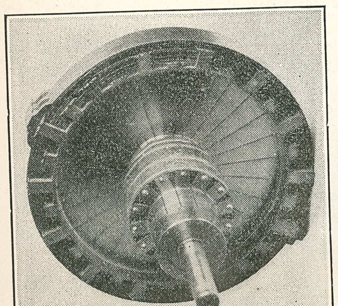
in its own plane and a magnetic needle placed over it, the needle would rotate in the same direction. In 1831 Faraday rotated a copper disc between the poles of a magnet and found that he received a current when he placed a copper brush at the center of the disc and one at its circumference and connected them to a galvanometer.

Edison's disc machine armature consisted of twenty-eight radial copper pieces or bars, having a thickness of about 3/16 of an inch. These radial flat copper bars were so shaped that they could be connected in a manner similar to the connection made in a drum armature by means of copper bands at the circumference. The commutator had fourteen sections and the whole armature with its shaft weighed about 33½ pounds.

The effective length of the radial bars that were subjected to the lines of force from the field magnet were only 3½ inches long. The diameter of the disc, including the connecting bands at the circumference and their insulation, was only 11½ inches.

The radial bars revolved in a magnetic field, the air space of which was only 11/32 of an inch. The patent drawings of the Edison disc machine showed only sixteen radial bars, and from them the mode of connecting the bars to the commutator can be seen, while at the same time the manner of connecting the bars with the proper one on the other side of the disc explains itself.

The lower illustration shows a central horizontal section of the machine and

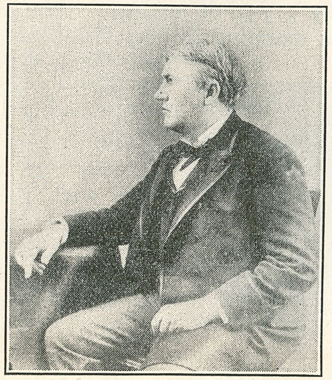


Front view of radial flat copper bar armature.

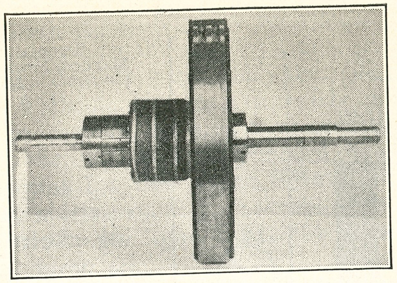
the position of the armature in the field magnet. The resistance of the armature with twenty-eight radial bars from commutator brush to brush, as I measured it on May 20, 1881, was 0.02165 ohms, and the speed was 1,200 r. p. m. when I tested it. With the armature open I obtained the following curve when the machine armature ran at 1,200 r. p. m.:

Voltage applied on field magnet coil	Voltage received at the armature
2.7 volts	31 volts
3.1 "	33 "
3.4 "	35 "
3.7 "	37 "
4.9 "	43 "
5.5 "	46 "
6.7 "	49 "
8.2 "	52 "
11.0 "	57 "
15.7 "	61 "
29.0 "	66 "

I made out my report and sent it to Edison in New York. He informed me that he would come to the laboratory on Saturday, May 23, 1881.



EDISON in 1893.



Side view of Edison's disc dynamo.

XC. The Jumbo Dynamo—

(PART THREE)

ON EDISON'S arrival from New York City, he instructed me to make a copper resistance having about 0.35 ohms, put it in water and keep it cool by letting fresh water run into the container. We then ran the disc machine at 1,380 r. p. m. and connected the armature to it, while, at the same time, it supplied the current for its own field. We ran it for some time and the armature remained cool.

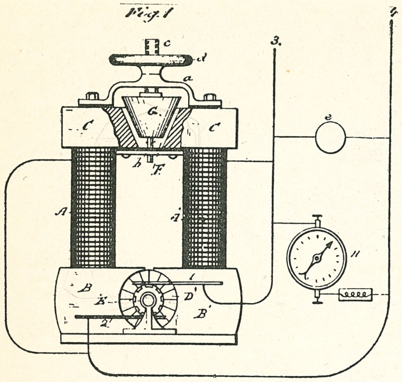
Edison said: 'Francis, connect the machine to all the Menlo Park demonstration lines.' These with the lamp across them had a resitance of 0.26 ohms.(1)

Edison was elated with the experiment, for the machine had held out and become only slightly warm. He said: 'It could run all day like that.'

He talked about building a larger one on this principle, and thus obtain all the pressure necessary for his lamp circuit. He speculated that the half of the twenty-eight radial bars being in multiple with the other half amounted to only about fifty inches of effective tension length, and that gave sixty-six volts on open circuit when running at 1,200 r. p. m.

'It's good,' he said, 'and if I make those radial bars about ten inches in length and thicker, I shall have to have a shaft as large as that on the "busted" Porter engine-dynamo.'

(1) This includes leakage or ground on the system.



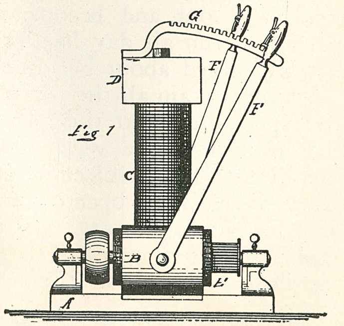
Patent drawing from application for 'Regulator for Dynamo or Magneto Electric Machines.' No. 263,134.

I may add that the results were very gratifying. I often wonder why he never followed them up. No doubt, his attention was at that time completely taken up with his new shops and the task of introducing his system to the public. The machine was shown at the Paris Electrical Exposition of 1881, and today it can be seen on the ground floor of the Edison Menlo Park laboratory in Dearborn, Michigan.

Another precious Edisonian relic Mr. Ford has obtained now stands by the disc dynamo. It reveals the experiment we made in weakening or strengthening the magnetism of the field magnet by creating more or less air space at the magnet's yoke.

In the yoke of the dynamo he cut a bevel aperture, into which he fitted a bevel piece of iron that could be raised or lowered.(2) Through this he strengthened or diminished the mass of yoke iron, and thereby strengthened or weakened the effective force of the field. His object was to try it for the purpose of regulation, that is, keeping the tension or pressure on the line constant when the current varied.

We also tried other ways of diverting the lines of force in the field magnet, so that



Drawing from application for Patent No. 263,136. Filed May 17, 1881. Granted August 22, 1882. Regulation of dynamo through short circuiting the magnetic lines of force.

(2) See U. S. Patent No. 263,134.

the pressure could be regulated by such means. Heavy iron levers were attached to the magnet's pole pieces and could be brought into contact with the yoke. The illustrations of Edison's U. S. Patent No. 263,136 clearly explain the idea.

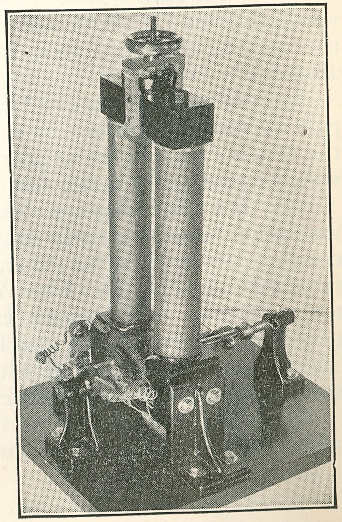
It would be difficult to give a comprehensive detailed explanation of the numerous experiments that were made at Menlo Park during the time when Edison was working on his greatest problem, namely, harnessing electricity and making it serve men for light, heat, power and many other purposes.

Many were the experiments to produce the practical lamp; many were the trials to make the dynamo an efficient converter of mechanical power; many were the experiments in self-regulation of varying currents, employing methods that today could be solved with pencil and paper—yet, with the primitive knowledge that was on hand at the time, there was only one recourse—experiment.

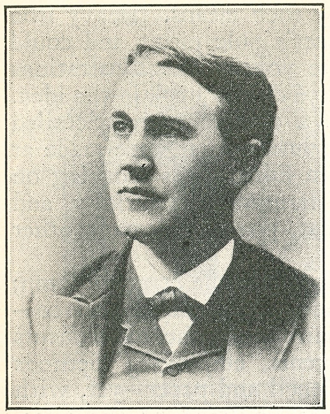
Just to mention the many subjects taken up experimentally at Menlo Park would fill pages. All merged together produced that grand system of current production and its transportation to distant localities for consumption. This system was the successful culmination of the labors of the grand young man of Menlo Park.

The results of his work led scientists and brilliant men to fathom other things which could not have been found had not young Edison uncovered the fundamentals, upon which they based their achievements.

His numerous accomplishments seem simple when looked upon with a naive eye, as many men did at first, when they attempted to cry him down as a charlatan. Many of these same men, when called upon to teach



Magnetic field regulating dynamo made at Menlo Park in 1881. Now in restored laboratory, Dearborn.



EDISON, 1885.

others, had no patience with what they called a 'dabbler,' nor did they have any prescience of the great art he was building up.

Without mathematics, Edison gave such tangible results that others were able to produce volumes of mathematical treatises, after he had furnished the basic fundamentals upon which they could build their theories. We well know how many cardboard theories have crumpled away in the past because their originators had no firm foundation upon which to build. Edison's coming to Menlo Park and the successful work he accomplished there not only laid the foundation of a great industry, but also the foundations for many theories that have been derived from his labors.

I have digressed from my subject due to my enthusiasm for the great man whose footsteps I had the privilege to dog while at Menlo Park. I was thrilled to see how he unraveled the secrets, the vista that he opened for others who came after him.

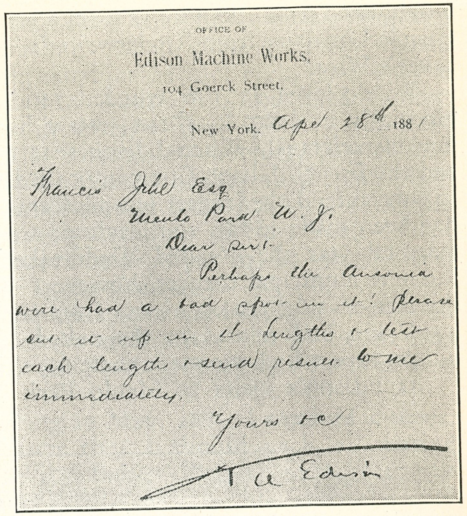
Let us return to the old Menlo Park laboratory in the early part of 1881. Another of my duties was the measuring of the conductivity of the copper wire that copper manufacturers were beginning to make for electric light purposes.

At that period good insulated wire was scarce. The insulation was miserable and the copper was impure; its conductivity was far below standard. As the samples arrived in our headquarters in New York City, they were rushed to me at Menlo Park, where I measured their resistance and noted their cross section and length at a known temperature. Then from the standard of what pure copper should be at the same temperature, I calculated its conductivity.(3)

The note that Edison sent me from New York on April 28, 1881, is an example of how he kept tab on my work. When

(3) I note from my diary that a Detroit copper works also sent samples.

Note from Edison to Jehl about testing insulation.



OFFICE OF
Edison Machine Works,
104 Goerck Street.
New York, Apl 28th 1881

Francis Jehl Esq
Menlo Park N. J.
Dear Sir:-
Perhaps the Ansonia wire had a bad spot in it. Please cut it up in 12 lengths & test each length & send result to me immediately.
Yours &c
T A Edison

some measuring results did not seem good to him, he gave orders to verify them in a different manner, in order to check. The Ansonia Copper Works was one of the first in the field to manufacture wire for incandescent lighting purposes. While I was still at the Menlo Park laboratory and Edison was in New York, he intrusted me with all the insulation tests of the wire which manufacturers were offering.

The insulation on wiring conductors for lighting was very bad. Like all new industries, it required time and capital to create new machinery. Fire underwriters' rules had to be drawn up. At first they sought the assistance of the electrical people who really know very little on that subject. One of the first rules of the New York Board of Underwriters(4) was: *Wires to be thoroughly insulated and doubly coated with some approved material.* (Ha-ha.)

As time went on improvements were made, and in about four or five years satisfactory insulated wire appeared on the market, although there was still further room for improvement.

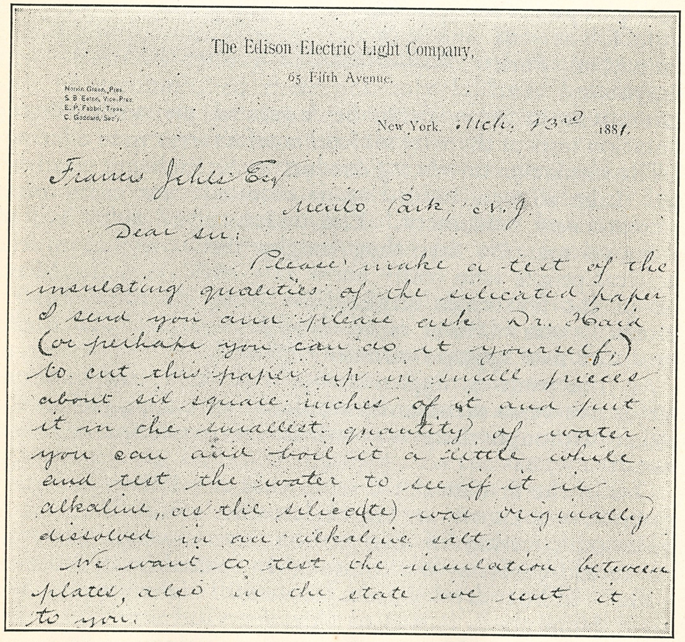
One of the first insulated wires that the Edison company employed was known as 'The Underwriter's Wire.' It had an insulation covering of two cotton layers woven onto it. The cotton covering was thoroughly soaked with chloride of zinc. In hot, dry localities, it was all right for pioneers, but in damp places it was terrible, for all the moisture was absorbed by the chloride of zinc, and in some cases water

(4) October, 1881.

would drop from the wire as from a leaking pipe. The 'boys' changed its name from 'Underwriter's Wire' to that of 'Undertaker's Wire.'

Wire placed in the wooden mouldings of those days, especially in damp localities, was a horror and terror to the first electricians. When Edison sent me to Europe in 1882, and the French Edison Company called me to Brunn, Austria, to superintend the largest incandescent light installation that had been made so far, the insulated wire that came with the material was the dreaded 'Undertaker's Wire.' We wired the new municipal theater, however. Before long, I ordered the men to take that wire out from time to time, tear off its insulation and reinsulate the naked copper wire with our Edison tape which we made there for this purpose.

As Edison's visits to Menlo Park became less frequent


The Edison Electric Light Company,
65 Fifth Avenue.

Norvin Green, Pres.
S. B. Eaton, Vice-Pres.
E. P. Fabbri, Treas.
C. Goddard, Sec'y.

New York. Mch. 23rd 1881.

Francis Jehl Esq
Menlo Park, N.J.

Dear Sir:

Please make a test of the insulating qualities of the silicated paper I send you and please ask Dr. Haid (or perhaps you can do it yourself) to cut this paper up in small pieces about six square inches of it and put it in the smallest quantity of water you can and boil it a little while and test the water to see if it is alkaline, as the silic(ate) was originally dissolved in an alkaline salt.

We want to test the insulation between plates, also in the state we sent it to you.

Edison orders Jehl to make some tests on insulation, etc. Letter was penned by Insull and signed by Edison, although signature is missing. Jehl gave it to an autograph collector.

I took care of visitors who came at night to see his lamp and system in actual operation. Then came the time when Edison very seldom appeared at Menlo Park, and only a few of us were left there to carry out orders from headquarters.

Edison had much to do in New York City. Aside from getting his manufacturing companies in order, particularly his Goerck Street Machine Works, he had to prepare plans for the erection of a central station. On April 19, 1881, the Edison Electric Illuminating Company of New York offered $750,000 of its capital stock at $100 par to the stockholders of the Edison Electric Light Company.

All this meant a great amount of hard thinking that soon had to be put into effective realization. It was then that plans for construction of the Pearl Street Central Station were started.

On a beautiful morning in May, 1881, I received a short, laconic note from Edison that I should pack all testing instruments, as well as the Bunsen Photometer, the top of the testing table, standard cells and everything that I would need to start a testing department at the Goerck Street Machine Works.

This news came as a bombshell. In the first place, I hated that part of New York City where the machine works were located. A young sentimentalist, I loved the laboratory with its soothing seclusion in God's open country, away from the beaten tracks of men. Now I was called upon by Edison to leave this secluded spot that I loved so much, and where I always had felt so contented, to go to a New York City slum district where gloom and foul air prevailed. What a contrast!

I had always thought that Edison would never give up Menlo Park, that he would return when the urgencies of affairs in New York were over. I had no business aspirations at that time. I was only joyous at being with Edison, at experimenting in his laboratory. It seemed to me that laboratory and Edison were inseparable, regardless of what might come. So I did not welcome the change. I recalled past years and the many incidents through which I had lived with Edison in that laboratory.

Brilliant history had been made here, to endure as long as light and sound are capable of being perceived by the senses of mankind. Menlo Park with its laboratory was a shrine, Edison was the high priest, and we 'boys' were his followers,

I had devoted all my energies in loyal obedience to the cause.

I was already saddened when Upton, Batchelor, Hammer, Force and others had been called away. I saw, but did not want to see, the gradual disintegration of the laboratory force. Then followed Clarke and Kruesi with others, our family continually dwindling, and the bright days of friendly fellowship passing away.

There was some consolation in the fact that all the testing instruments and accessories, even the top three-plied wooden board that rested on the brick piers to form the testing table, were to go with me in my transfer. With them taken away, the whole plexus of the laboratory faded. What could the old place amount to when electrical and photometrical measurements could not be made—just an empty-shell memory of great days that have passed!

As I descended downstairs, I met Acheson and, before I had a chance to tell him the bad news, he asked me: 'What's up, why so glum?' I told him of my orders.

'Why,' he answered, 'you ought to be glad to get away from here, now that Edison has practically given up the place. In a few months, after they have finished the instruments and other stuff that Edison wants to exhibit in Paris, most of the men in the machine shop will leave too. Then there will be only two or three left to show the electric railroad.'

Acheson told me that he had received a message to go to the lamp factory for a period of preparation, as he was to accompany Cunningham and Hipple to Paris, where Batchelor was to take charge of the Edison exhibit at the Electrical Exposition. He added that he already had a job. Edison wanted him to make a show case displaying how the bamboo is processed, from its raw state to a carbonized filament, and another showing the process of blowing the glass parts of the lamp from the raw glass rod to the finished lamp, with filament and base.

He also told me that he had heard that Dr. Moses was going to Paris because he spoke French, and that Dr. Nichols was already at the lamp factory along with Lawson.

'The place will be empty,' he said. 'Come on, old boy, let's take a walk to Metuchen and have luncheon there where we can talk things over, perhaps for the last time, for soon all of us will be scattered.'

It was a beautiful May morning and as we walked we talked about our future prospects and of the great work that

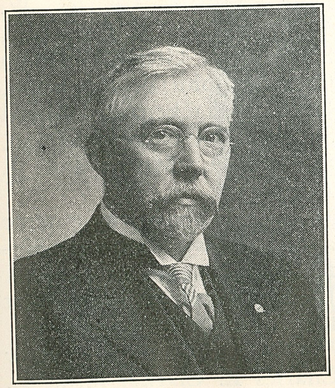
Edison had accomplished, and the many new vocations he had created. We agreed that it would mean business in every country and an unprecedented revolution in the affairs of mankind. We recalled the great advantage that we had had while working with him and the manner in which he conducted his work, experimenting to obtain results and, if none were forthcoming, to find out why—all of which was so realistic and abounding with common sense.

We talked about the few special men of the laboratory that Edison had picked to help him start the introduction of his system commercially. The talk turned to James M. Seymour. We wondered why he did not strive to get into the incandescent lighting line.

In Volume I, Page 282, I erred in stating that Seymour did not go to London for Edison. He has written me:

'Mr. Edison sent me to London on January 5, 1880, to take care of the Motograph telephones which did not like the moist climate there. In September, 1880, the Bell and the Edison companies consolidated and Mr. Gardner G. Hubbard, the father of the Bell company, offered me a fine position in Belgium, which I accepted. I went to Antwerp, then Sweden, Holland and Russia. I took time off and helped Hammer install the light plant in Holborn Viaduct.'

Seymour returned home in 1888 and settled in Newark, New Jersey, and has since practiced as an electrical and mechanical engineer.



JAMES M. SEYMOUR

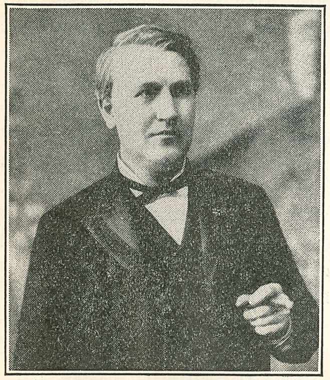
After I had packed the laboratory instruments, and all, and had said goodbye to the men at the lamp factory and machine shop, I found my way to the railway station, bound for New York. Menlo Park was, from that moment, the past. When I caught my last glimpse of the once-loved laboratory from the train, a thousand memories flashed before me, only to be disturbed by the shrill voice of the conductor shouting: 'Tickets!'

A word in conclusion:

In justice to the men, as well as to the history of applied electrical energy, I wish to give the names of the men who once clustered about Edison when he accomplished the greatest achievements of his life, that period which gave to the world the universal Edison who will always be remembered as the Edison of Menlo Park.

Among the names given below, the reader will find those who were his assistants and helpers during his creative epoch; that is, up to the time when the first practical lamp was perfected on October 21, 1879. Then follow the names of those who came after October 21, 1879. Incorporated among the two rosters, will be found the names of the first Edison pioneers of incandescent lighting, while who was who and what can be found in my 'Menlo Park Reminiscences.' They are the men whom Owen D. Young described as the apostles of the electrical industry. They were the first Edison pioneers of incandescent lighting, unselfish men who remained loyally at his side and assisted their master in promulgating and instructing others in the work he had accomplished.

Before October 21, 1879: Charles Batchelor, John Kruesi, Francis R. Upton, Francis Jehl, Martin Force, James Seymour, John W. Lawson, Dr. A. Haid, Ludwig Boehm, Charles Dean, John Ott, James J. Bradley, John Hood, David Cunningham, Patrick Kenny, Thomas Logan, James A. Lighthipe, Milo Andrus, Charles W. Moffett, Henry A. Campbell, Stockton L. Griffin, William Carman, John F. Randolph, J. U. Mackenzie, Alfred Swanson, George Carman, Samuel D. Mott, and J. Ayers.



EDISON in 1903.

To the above, as outside assistants, we must add: Sigmund Bergmann, Edward H. Johnson, and we must not forget Major McLaughlin.

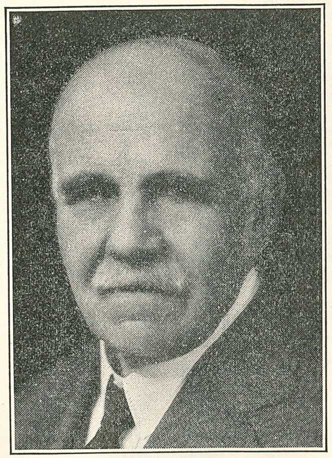
After October 21, 1879: Charles L. Clarke, Julius L. Hornig, Wilson S. Howell,

William J. Hammer, Edward G. Acheson, Dr. Edward Nichols, Dr. Herman Claudius, Dr. Otto Moses, George Hill, Albert Herrick, George Crosby, William Mills, Patrick Segadore, William H. Moore, David Hickman, C. Van Cleve, William Holzer, James Hipple, George Hickman, William S. Andrews, James Holloway, John H. Vail, Alexander Mungle, Anton R. Westerdahl, John Kelly, George Dean, Charles Flammer, Hugo Andersson, Hermann Lemp, Rene Thury, William Wright, W. Raymon, J. Knight, Messrs. Isaacs, Poiner, Tweed, Charles T. Hughes, Ernest T. Berggren, Edward C. Rowland, Charles P. Mott, William Bogan, and Philip Seubel.

We had floaters and laborers at Menlo Park now and then, but I am almost sure that no name of the least significance has been omitted.

In 1881 Edison drafted some of his old helpers and went to New York to create a new group of pioneers to further the exploitation of his system of domestic lighting.

—*Francis Jehl.*



FRANCIS JEHL, 1938

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